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European Network of
Transmission System Operators
for Electricity

QUALITY OF CGMES DATASETS AND CALCULATIONS

FOR SYSTEM OPERATIONS

VERSION 3.2.1 – SOC APPROVED

27 APRIL 2022

COMMON GRID MODEL BUILDING PROCESS (CGM_BP)

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NOTE CONCERNING WORDING USED IN THIS DOCUMENT

The force of the following words is modified by the requirement level of the document in which they are used.

- MUST: This word, or the terms “REQUIRED” or “SHALL”, means that the definition is an absolute requirement of the specification.
- MUST NOT: This phrase, or the phrase “SHALL NOT”, means that the definition is an absolute prohibition of the specification.
- SHOULD: This word, or the adjective “RECOMMENDED”, means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications shall be understood and carefully weighed before choosing a different course.
- SHOULD NOT: This phrase, or the phrase “NOT RECOMMENDED”, means that there may exist valid reasons in particular circumstances when the particular behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
- MAY: This word, or the adjective “OPTIONAL”, means that an item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because the vendor feels that it enhances the product while another vendor may omit the same item. An implementation which does not include a particular option MUST be prepared to interoperate with another implementation which does include the option, though perhaps with reduced functionality. In the same vein an implementation which does include a particular option MUST be prepared to interoperate with another implementation which does not include the option (except, of course, for the feature the option provides.).

Change History

2019-12-20 LOO First draft of QoCDCv3.2

2020-05-13 LOO Since v3.1 the following rules has been added, renamed or deleted

- Level 1
  - SynchronousArea renamed to CGMRegion
  - SourcingTSO renamed to SourcingActor
- Level 3
  - SMRatedSunrealistic
  - TargetDeadbandOutOfRange
  - WindingConnectionAngle
  - VoltageLimitDirection
  - VoltageLimitsConsistency
  - FlowLimitsDirectionConsistency
  - AsymmetricalEquivalent
  - PositiveTransformerB
  - GeneratingUnitSM
  - SMPLimits
  - SubLoadAreaMissing
  - EnergyAreaMissing
  - CurveXYValue renamed to CurveXValue
  - SMQLimits4 has been removed as covered by SMPLimits
  - RCCXValues1 has been removed as covered by RCCXValues2
  - DCNodeContainment removed as covered by cardinality
- Level4
  - IncompleteObject renamed to IncorrectAttributeOrRoleCard
  - CgmSvSshVersionMismatch
- Level 5
  - SvPowerFlowBranchInstances2
  - SynchronousCondenserMode
  - TCCRemoteReactiveFlow
  - EquivalentInjectionContainment moved from level 3 to level5
  - DCLineContainment moved from level 3 to level5
- Level 6
  - FakeVoltage
- Level 7
  - InconsistentTnBaseVoltage
  - ACScheduleMatch1

ACScheduleMatch2

Level 8

TIConvergenceStatMissing

TIConvergenceStatDiverged

2020-03-27 Rule SynchronousArea renamed to CGMRegion and field <synchronousArea> renamed to <cgmRegion>

2020-03-31 sanity check, adding missing cim: prefixes and format check.

2020-04-06 Rule RCCYValues simplified with text from CGMES3.0. Rule LRCExponentModel changed to allow exponents in the range 0 =< exp =<2. Rule RatedS exception for aggregated flag=false removed.

2020-04-06 LRCExponentModel exponent values restricted.

2020-04-06 Rule RatedS changed to ignore aggregate flag.

2020-04-06 Rule CGMRegion severity not correct, changed WARNING->ERROR

2020-04-21 Rule severity revised to match CGM_BP requirements.

- SourcingActor WARNING->ERROR
- SVCSlope WARNING->ERROR
- PhaseCodeGround WARNING->ERROR
- SVCVoltage WARNING->ERROR

2020-04-21 Consistency checks made, e.g. match between severity and shall/should, presence of “cim:” prefixes, spelling, reference to limits etc.

2020-05-11 Changes according to comments from Jun Zhu.

2020-05-12 Updates based on CGM ICT comments. New section “Supporting documents” added.

2020-05-13 Prepared for publish.

2020-05-19 EquivalentInjection moved from rule BranchBaseVoltage to CEBaseVoltage. SeriesCompensator is tested by rules BranchBaseVoltage and CEBaseVoltage, it is removed from rule BranchBaseVoltage. Equivalent shunt added to rule CEBaseVoltage.

2020-06-10 Rule MASPersistency moved back to level 2 from level 5.

2020-06-10 Spelling errors corrected and incorrect sign statement in rule GeneratingUnitNominalP corrected.

2021-06-14 A new version v3.2.1 (release candidate) of QoCDC is opened. This is a track change version. Summary of changes in version 3.2.1:

- Various editorial changes are applied
- For reference data the reference to QoCDC Reference Data document is used in the whole document
- The following rules are modified to decrease the level of ambiguity: FileNameMD, FileNameConsistency, EffectiveDateTime, NameLength, EFCContainment, OperationalLimitSetAtTerminal, PATL2, PowerTransformerEndR, PowerTransformerEndX, RatedS, WindingConnectionAngle, VoltageLimitDirection, GeographicalRegionBD, SVCVoltage, BranchBaseVoltage, CEBaseVoltage, ParticipatingGeneratingUnit, RequiredSvSCSections, RequiredSvTapStep, MAS, MASPersistency, PhaseCodeGround, ValidResourceValue, URNUniqueness, AttributeAndRoleValues, DCEquipmentContainerMapping, SvInjectionLimit,

TIConvergenceStatMissing, TargetDB, TargetDeadbandOutOfRange, EquivalentBranchX, TerminalCount1, TerminalCount2, TerminalSeqNumOrder, MeasTerminal, AcceptableDuration, CNRequiredInEQOperations, ControlModeCompatibility, ModelDescription, SwitchOpenVsConnected, SvPowerFlowBranchInstances, InconsistentCurrentLimits, CGMCongestion, InconsistentTnBaseVoltage, ACTielineBV, ControlOfAnotherIsland, VoltageTargetsAtTN, EquivalentInjectionControlEnabled, TapChangerTargetRange, TCCRemoteReactiveFlow, ShuntQ, DERActivePowerInfeedDiffE, NetInterchange1, NetInterchange2, VoltageTargetAndDeadbandAtTN, ControlAreaInstance. UnpairedTieFlow, GenActivePowerInfeedLim, SynchronousCondenser, DCLineContainment, CGMTieFlowImbalance, GeneratingUnitMaxPGen, LRCExponentModel, LCRCoefficientModel, SMPLimits, EIActivePowerInfeedLim, ENIActivePowerInfeedLim, EIReactivePowerInfeedLim, ENIReactivePowerInfeedLim, ModelCreated, ScenarioTime, PowerTransformerEndRatedU, TapPosition, RCCXValues3.

- The following ruled are modified/deleted to fit to the present way of exchanging: ModelingAuthority is deleted, MCFirst and MCSecond are replaced by rule MCFirstSecond, ReactiveControlAtBus is deleted, EIReactivePowerInfeedDiffW was replaced, CGMVoltageProfile is deleted, GeneratingUnitLimits is deleted.
- The rules that require references to ISO country codes use codes for countries defined in QoCDC Reference data document.
- Table 2 is modified.
- Section 2.11 is modified and most of the content is moved to section 12. Further changes are expected in section 12, but this is informational section and not critical.
- Section 2.12 is introduced.
- Section 3.2 is introduced and parts revised.
- Section 5.4.1. was added to provide additional information regarding generation limits. Various rules are built on that information.

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1 SUMMARY

The document “Quality of CGMES Datasets and Calculations” aims to increase the quality and consistency of power network model data that is exchanged to support the following processes:

- Coordinated security assessment;
- Coordinated Capacity Calculations;
- Unavailability Planning Coordination;
- Short-term & Medium-Term Adequacy
- After-the-fact analysis of events;
- Ad-hoc system studies;
- System development planning;
- Dynamic Stability Assessment;
- TYNDP and other strategic system studies;
- Inter TSO compensation;

Quality is a concept that can be expressed as the “fitness for purpose” for a target process. This entails that the exchanged data can be processed, is consistent and is interpreted the same way by all users (in other words: is interoperable) and will lead to plausible calculation results. It also means that the data can be processed smoothly in an automated (machine to machine) environment without the explicit need for human intervention. This document contains 8 levels of validation further described below.

2 INTRODUCTION

2.1 OVERVIEW

The purpose of this document is to consolidate and structure the necessary quality criteria and quality indicators that are applicable to the CGMES instances files used by TSOs and RSCs in order to produce plausible Individual Grid Models (IGMs) and Common Grid Models (CGMs) that are fit for purpose for subsequent business processes, such as:

- Coordinated security analysis
- Coordinated Capacity Calculation
- Unavailability Planning Coordination
- Short-term & Medium-Term Adequacy
- After-the-fact analysis of events
- Ad-hoc system studies
- System development planning
- Dynamic Stability Assessment
- TYNDP and other strategic system studies
- Inter TSO compensation

The first four bullets are defined as RSC services, the following bullets are processes covered by regional processes and TYNDP.

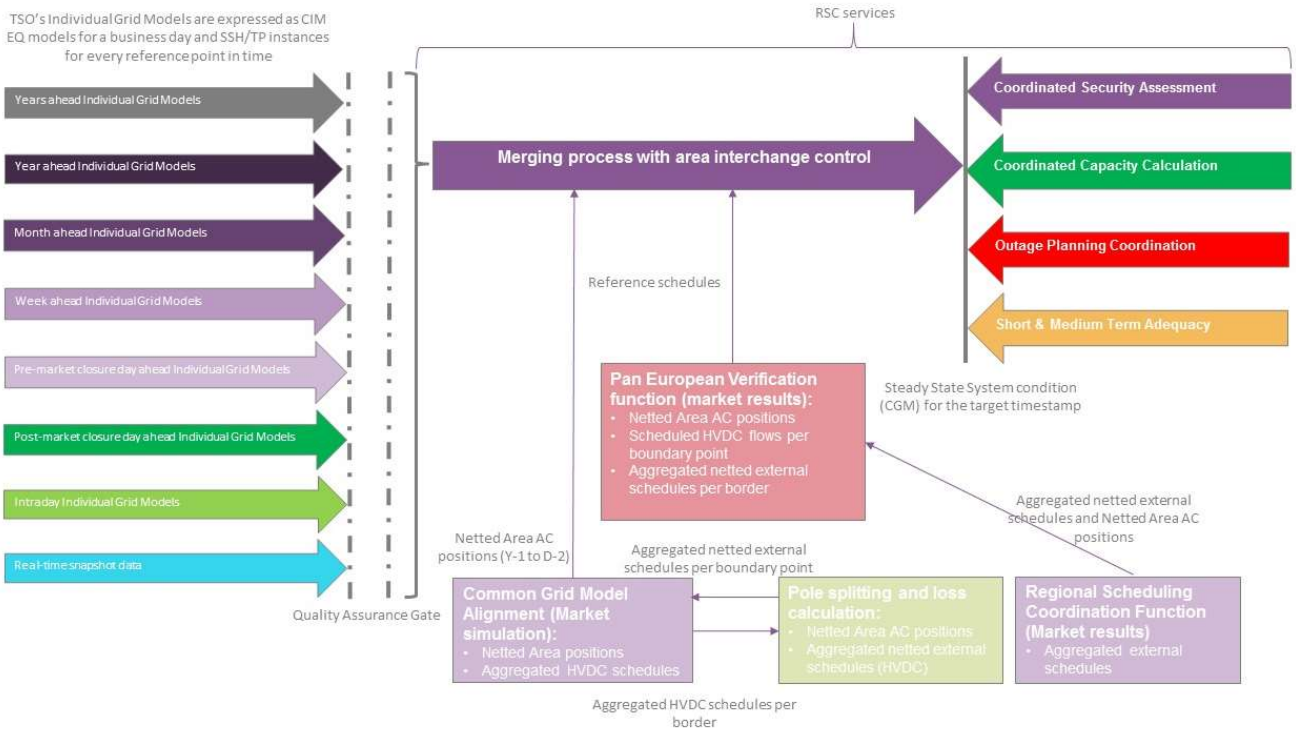

Figure 1 Context of operational data exchanges leading to Common Grid Models

Netted Area AC positions and scheduled flows on HVDC interconnectors (necessary input data for the merging process) is exchanged in the Reporting Information Market Document, based on ESMP (European Style Market Profile), IEC 62325 series[1]. The validation of the scheduling data that is provided in these documents is not in scope of this document. The schedules themselves are used for coordination validation.

The first edition of this document was issued on the 2nd of May 2016. The second edition of this document was approved by ENTSO-E System Operations Committee on the 12th of October 2016 to act as input for the design of the three Quality Gates:

- Local Quality Gate, covering first three validation levels;
- Global Quality Gate, covering levels 4-7;
- EMF Quality Gate, covering level 8.

This edition incorporates experience gained while running interoperability tests, revealing the need for additional validation rules and improving some existing rules.

As the QoCDC document evolved new rules has been defined and old revised. The rules are aligned with CGMES 2.4.15 specification and the consolidated CGMES specification that is evolving in parallel with the QoCDC.

Although this document is designed for system operation it includes useful rules applicable for TYNDP and other processes. Hence the rules defined here are may also be used in other processes not directly covered in this document.

This document collects experiences from implementing CIM and CGMES and can be seen also as an input to the CGMES roadmap and potentially integrated in future releases of CIM and CGMES documents.

Hopefully the document can also influence developing extensions of CIM as well as profiling methods supporting more efficient integration of market and network data.

2.2 PRECONDITIONS FOR AUTOMATED MERGING

For an interrupt-free, automated exchange process (i.e. without human interference), several criteria need to be met. The criteria are specified at several levels where level 1 is the most basic and done first followed by the higher levels in order.

Level 1 covers meta data in file names and packaging of CIMXML files.

Level 2 covers the structure and syntax of the individual CIMXML files as well as the meta data header.

Level 3 covers constraints that can be evaluated within the scope of the CIMXML files.

Level 4 covers issues that can be detected during model assembly.

Level 5 covers cross profile consistency of data

[1] IEC 62325 documents are based on transactions between parties and areas, identified by EIC mRIDs. For the CGM processes, we identify ControlArea by UUID/Legacy ID and use an attribute to specify EIC code for this area. External mapping can be applied to link instance data exchanged via the two standards.

Level 6 collects diagnostic information that may help solve convergence issues by identifying modelling issues that seem troublesome.

Level 7 focuses on coordination of IGMs in terms of neighbouring TSOs and reference values.

Level 8 focuses on convergence behaviour of IGMs and CGMs and on the plausibility of the CGM.

The steps in the automated process and where the validation levels appear in this process is shown in Figure 2.

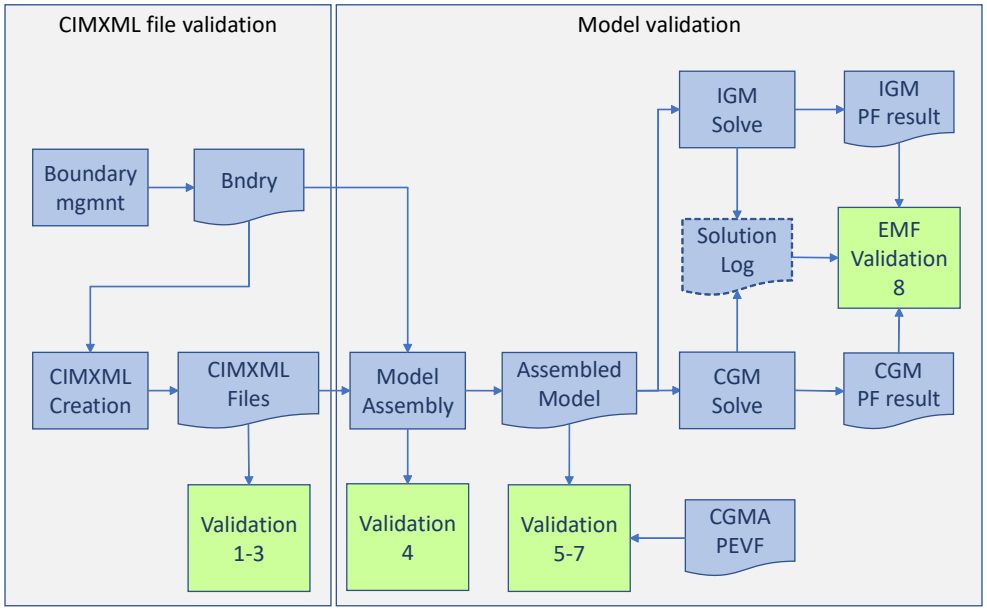

Figure 2 The Automated process annotated with validation levels

The symbols in Figure 2 has the following meanings:

- Blue box – data processing.
- Blue document – CIMXML file or another file.
- Green box – validation.

The green boxes in Figure 2 show where the validation according to the levels 1 to 8 appears in the automated workflow.

The workflow steps are:

- Boundary management (Boundary mgmnt) where the boundary is created (Bndry), this is a manual process at this point, should be automated eventually. The process description is out of scope of this document.
- IGM or CGM creation where CIMXML files are created. This is a TSO or RSC internal process. This process description is out of scope of this document.
- Once CIMXML files have been created, they are automatically uploaded to OPDM (not shown in Figure 2) where they are validated with levels 1 to 3 rules.
- CIMXML files are assembled per EffectiveDateTime into models. The assembly process is validated with level 4 rules.

- The assembled model is validated with level 5, 6 and 7 rules.
- The assembled model, IGM or CGM, is solved in power flow for each EffectiveDateTime and the solution is validated with level 8 rules.

The rules at levels 1 to 6 should block publication to OPDM if the severity is ERROR. The rules at levels 7 and 8 should not block publication regardless of severity. It is advisable to have this as a configuration option in the implementation of the rules.

2.3 GUIDING PRINCIPLES

The following principles for validation and rejection of data apply:

- **Fit for purpose**: the validation rules only focus on issues that may impact the business process/usability of the models. Rejection (error level) only applies if the data cannot be processed further in the business process or harms the subsequent processes.
- **Selectivity**: rejection of bad data shall be done on the smallest unit of data.
- **Traceability**: if a process fails, it shall be possible to trace back the root cause (adequate messages and diagnostics).
- **Harmonization**: power flow settings and automatic corrections are predefined.
- **Maintainability**: validation rules are specified in XML syntax of the rules is specified in XSD. Instructions for implementation of the validation rules are provided in the XML.

2.4 NORMATIVE REFERENCES

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- IEC 61968-100:2013, Application integration at electric utilities – System interfaces for distribution management – Part 100: Implementation profiles
- IEC 61970-301:2016 RLV (Red Line Version), Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base
- IEC 61970-452:2017 (Edition 3.0), Energy management system application program interface (EMS-API) - Part 452: CIM static transmission network model profiles
- IEC 61970-453:2014 (Edition 2.0) and AMD1:2018 CSV, Energy management system application program interface (EMS-API) - Part 453: Diagram layout profile
- IEC 61970-501:2006 (Edition 1.0), Energy management system application program interface (EMS-API) - Part 501: Common Information Model Resource Description Framework (CIM RDF) schema
- IEC 61970-552: 2013 (Edition 1.0), Energy management system application program interface (EMS-API) - Part 552: CIMXML Model exchange format. The older ID formats according to section 6.4 is allowed.

- IEC TS 61970-600-1:2017, Energy management system application program interface (EMS-API) - Part 600-1: Common Grid Model Exchange Specification (CGMES) - Structure and rule [2]
- IEC TS 61970-600-2:2017, Energy management system application program interface (EMS-API) - Part 600-2: Common Grid Model Exchange Specification (CGMES) - Exchange profiles specification
- IEC 62325-451-1, Framework for energy market communications – Part 451-1: Acknowledgement business process and contextual model for CIM European market
- IEC 62325-451-5, Framework for energy market communications – Part 451-5: Status request business process and contextual model for CIM European market
- ISO 8601:2005, Data elements and interchange formats – Information interchange – Representation of dates and times
- Extensible Mark-up Language (XML) 1.0 (Fifth Edition), *W3C Recommendation 26 November 2008 (*https://www.w3.org/TR/2008/REC-xml-20081126/ *)*
- Key words for use in RFCs to Indicate Requirement Levels, *Network Working Group Best Current Practice, Harvard University March 1997* (https://www.ietf.org/rfc/rfc2119.txt)
- QoCDC Reference Data document

2.5 DOCUMENT HIERARCHY

The following document hierarchy is applicable:

1. IEC 61970 CIM UML16v28 and IEC 61968 CIM UML 12v08 are used as the standard for the network model exchanges
2. CGMES 2.4.15 profile available as a UML information model with file name ENTSOE-CGMES_v2.4.15_Aug2014_XMI.zip, Refer also to https://www.entsoe.eu/digital/common-information-model/
3. IEC TS 61970-600-1:2017 and IEC TS 61970-600-2 Ed1 (CGMES 2.4) is a subset of the IEC canonical information model and adds some ENTSO-E extensions to the standard and specifies the profiles in CIM RDF XML in which the Individual grid models (IGMs) and Common Grid Models (CGMs) are exchanged
4. EMF Requirements specification (current approved version 2.0) specifies the merging process from individual Grid Models (IGMs) to Common Grid Models (CGMs). Refer also to: https://extra.entsoe.eu/SOC/IT/WP%204/EMF%20requirements%20specification%20v2_final.pdf
5. This document consolidates the identified necessary validation rules to ensure integration of all components featuring IGMs and CGMs that are fit for purpose. This document is used together with QoCDC Reference Data document.

[2] The QoCDC document provides additional normative rules not covered by the IEC TS 61970-600 specifications. In a few cases they supersedes IEC TS 61970-600.

2.6 INFORMATION MODELS

The validation rules in this document relate to information models that describe the network data being exchanged, i.e. CGMES 2.4. The CIM/XML format (IEC 61970-552) used in this exchange has a header with meta data about the exchanged network data. As CIM/XML header does not cover all meta data needed, hence the file names have been used to carry additional meta data. To do this the file name string has been divided in pieces where each piece describes a specific meta data. Additionally, human readable file names were considered an important requirement, at least in the initial phases where the automated processes are not fully commissioned.

2.7 NUMBER PRECISION

Limited and possibly different precision in implementations of import/export tools as well as power flow solvers may result in small deviations of numeric values between IGMs. Hence it is advised to use a small tolerance in comparisons. The numeric tolerance was decided based on experience from empirical analysis of IGMs triggering the rules and is defined as a factor of 0.0005, used in comparison of values as follows:

- Value1
- Value2
- Abs(Value1 - Value2) < Abs(Value1)*0.0005 or
  Abs(Value1 - Value2) < Abs(Value2)*0.0005

The future amendments of this document may lead to change of the numerical tolerance, so it is advised to have this factor as configurable in the implementation of the rules.

See also FBOD5 from IEC TS 61970-600-1:2017.

2.8 GROSS VS NET PRODUCTION VALUES

The business process capacity allocation and congestion forecast use net production values, not gross values. Hence all production values shall be considered being net values. This also means that any instances of the GrossToNetActivePowerCurves class in an IGM shall not be present.

2.9 INTEGRATION OF VALIDATORS

Validation can be done by off-line validators that run as an executable program or script on a single file or a set of files in a folder and produce output in human readable form, and/or by client-server processes, such as designated quality portals that use “request” and “reply” messages in accordance with IEC 61968-100. The rule templates describing errors or warnings in this document are examples how tools may report errors and warnings. The XML templates are expected to be filled with the missing data when errors or warnings are reported.

2.10 TERMS AND DEFINITIONS

Table 1 specifies the terms and definitions that are used in this document. A more detailed description of some terms can be found in IEC TS 61970-600-1:2017.

452 **Table 1 Terms used and their definitions**

Term	Definition
Assembly	The process of combining information from a single Modeling Authority Set (serialized in separate instance files) into a coherent data set in which all RDF references have been resolved.
Base Voltage	Defines a system base voltage which is referenced when converting to per unit values inside power flow tools.
Boundary Information	Is a set of data related to the boundary points and related AC or DC interconnections. The boundary information includes at least identifiers and names of boundary points, substations, tie-lines.
Boundary Set	As defined in the CGMES, it is a dataset that contains all boundary points and ENTSO-E reference data necessary for a given grid model exchange. A boundary set can have different coverage depending on the requirements of the common grid model exchange. A complete boundary set is necessary to assemble a pan-European power system model.
Boundary Point (BP)	Boundary Point defines the point of common coupling between two Modeling Authority Sets (MAS). A Boundary point could be a ConnectivityNode or a TopologicalNode placed on a tie-line or in a substation. A Boundary point must be contained in a Boundary Set and must not be contained in the MAS of a TSO. A Boundary point is referenced by Terminals in the MAS of a TSO. ConnectivityNode and TopologicalNode are terms specified in IEC CIM standards.
CGM	Common Grid Model, i.e. the steady state pan-European system state for a given point in time.
CGMES	Common Grid Model Exchange Specification
DACF	Day Ahead Congestion Forecast
Dangling reference	A dangling reference is just like a broken link on the web. In a model assembly it's a reference to an identified object that should have a description in the assembly and, simply, doesn't.
EIC	The EIC (Energy Identification Coding scheme) is standardized by ENTSO-E for a unique identification of the market participants and other entities active within the Energy Internal European Market (IEM). Over and above Market Participants (Parties - object type "X"), the EIC also covers other entities by allocating a unique code to the following object types: Areas – object type "Y", Areas for inter System Operator data interchange Measuring Points – object type "Z", Energy Metering points Resource objects – object type "W", such as Production plants, consumption units, etc. Tie-lines – object type "T", International tie lines between areas Location – object type "V", Physical or logical place where a market participant or IT system is located Substations – object type "A"

Term	Definition
	The EIC is based on fixed length alphanumeric codes which can be broken down as follows: A 2-character number identifying the Issuing Office assigned by ENTSO-E. One Character identifying the object type that the code represents. 12 digits, uppercase characters or minus signs allocated by the issuing office 1 check character to ensure the code validity. Valid characters of an EIC code are A-Z, 0-9 and "-".
EQ	Equipment profile in CGMES, describing the physical property of equipment and its connectivity.
EQBD	Equipment Boundary profile in CGMES.
IGM	Individual Grid Model, i.e. all instance data that is necessary to specify a scenario as input and output for a power flow tool (e.g. EQ, SSH, TP and SV).
Merging	The process of combining information from multiple Modeling Authorities and external constraints into a coherent network model with operating assumptions for a given point in time.
Modeling Authority	The organization responsible for modelling its responsibility area.
Modeling Authority Set	A URN/URI referring to the organisation or role sourcing the model in the CIMXML document. Models from the same organisation or role but for different profiles shall have the same urn/uri. Different representation of the same responsibility area, e.g. system development planning model, shall have a different URN/URI if the models are different.
mRID	Master Resource Identifier. The IdentifiedObject class contained in the Core package of the Common Information Model (CIM) is inherited by all PowerSystemResource and many other classes. This class has attributes and associations to be used for naming all CIM objects. The mRID attribute of the IdentifiedObject class provides a straight forward and rigorous means of identity for CIM objects. The IdentifiedObject.mRID is a globally unique machine-readable identifier for an object instance.
OPDE	Operational Planning Data Environment
OPDM	Operational Planning Data Management (Smart file storage and management for Operational Planning Data including validation of file names, RDF/XML structure and syntax).
RDF	Resource Description Framework, as specified in https://www.w3.org/RDF/
rdf:ID/rdf:about	In RDF the rdf:ID identification has the specific meaning that the identifier is unique within a document while the rdf:about identification means the identifier is unique within a name space. If the UUID name space urn:uuid is used for the rdf:about identification the identifiers are globally unique. Hence CIMXML promote using rdf:about identification in the UUID name space for all identifiers.

Term	Definition
	The URN form is used as CIMXML element identification as follows: The prefix “urn:uuid:” is replaced by an underscore “_”. The underscore avoids a numeric starting character for the non-base part of the identifier. Starting the non-base part of the identifier with a numeric character is invalid RDF. The underscore is added in all cases to simplify parsers, even if the UUID starts with a non-numeric character. The prefix is defined as an xml:base=“urn:uuid:” Some examples: rdf:ID=”_26cc8d71-3b7e-4cf8-8c93-8d9d557a4846” the rdf:ID” form. rdf:about=”#_26cc8d71-3b7e-4cf8-8c93-8d9d557a4846” the “hash” form. rdf:about=”urn:uuid:26cc8d71-3b7e-4cf8-8c93-8d9d557a4846” the “urn:uuid:” form.
rdf:resource	Pointer to denote an association or used to reference an enumerated value. The value of rdf:resource is a “resource-uri”, which can specify an XML resource, using the “hash” form or the “urn:uuid:” form or an external resource or enumeration using a namespace prefix (http://....)
SSH	Steady State Hypothesis profile in CGMES, describing the switch and tap positions, control targets, as well as energy generation, consumption and border exchanges at one operating point (in time).
SV	State Variables profile in CGMES, describing the state variables of a power flow solution in terms of complex voltages and power flows.
TP	Topology profile in CGMES, describing the relationship between topological nodes and terminals.
TPBD	Topology Boundary profile in CGMES.
TYNDP	Ten Year Network Development Plan.
URI	Uniform Resource Identifier, i.e. a string of characters used to identify or name a resource.
URL	Uniform Resource Locator, a specific type of URI, which is a reference to a web resource that specifies its location on a computer network and a mechanism for retrieving it.
URN	Uniform Resource Name, a specific type of URI, used to identify a resource by name in a particular namespace. A URN may be used to talk about a resource without implying its location or how to access it.
UUID	Universally Unique Identifier[3], specified as follows: 8 character hex number a dash “-“ 4 character hex number a dash “-“ 4 character hex number

[3] The algorithm is aligned with, and technically compatible with, IEC 9834-8:2004 Information Technology, "Procedures for the operation of OSI Registration Authorities: Generation and registration of Universally Unique Identifiers (UUIDs) and their use as ASN.1 Object Identifier components" ITU-T Rec. X.667, 2004.

Term	Definition
	a dash “-“ 4 character hex number a dash “-“ 12 character hex number where letters are lower case

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2.11 RULES' CONSTANTS

Table 2 provides information on the constants used in the rules defined in this document.

Table 2 List of constants used in the rules

Constants used in the rules	Value	Unit with multiplier
NUMERIC_TOLERANCE	0.0005	Multiplication factor
SSH_SV_MAX_P_DIFF	10	MW
SSH_SV_MAX_Q_DIFF	50	Mvar
SSH_SV_TOT_P_DIFF	200	MW
SSH_SV_MAX_TAP_STEP_DIFF	2	Integer number
SSH_SV_MAX_Q_SHUNT_DIFF	1	Mvar
SV_INJECTION_LIMIT	0.1	MVA/MW/Mvar
EQ_BRANCH_X_LIMIT	0.01	Ohm
EQ_RATEDS_REASONABILITY_FACTOR	10	Integer number
EQ_DB_REASONABILITY_FACTOR	2	Integer number
IO_NAME_LENGTH	32	Integer number
IO_DESCRIPTION_LENGTH	256	Integer number
EIC_LENGTH	16	Integer number
SHORT_NAME_LENGTH	12	Integer number
BOUNDARY_BV_MAX_DIFF	0.1	Multiplication factor
PATL_LIMIT_VALUE_DIFF	0.1	Multiplication factor
INTERCH_IMBALANCE_WARNING	50	MW
INTERCH_IMBALANCE_ERROR	200	MW
INTERCH_IMBALANCE_EMF	2	MW

2.12 VALIDATION HANDLING AND REPORTING OF VALIDATION RESULTS

The following general rules are defined:

1) Validation engines shall always use the latest version of the QoCDC Reference Data document.
2) Many rules are checking basic and fundamental requirements. Non conformity with those rules would change the overall validation result and how it is presented to the users. In order to prevent that different implementations are providing completely different validations results and also to be able to facilitate the comparison of these results, it is recommended that users are given a possibility to select the outcome of the validation if the following rules are triggered. Either the validation is aborted, or the validation process continues, if possible, knowing there will be many errors/warnings reported due to side effect.
    - FileNameMD,
    - FileNameConsistency,
    - IDuniqueness,
    - DanglingReferences,
    - XMLStructure.
3) Validation engines shall report validation results in a user-friendly manner following the descriptions and messages defined for each rule. Some of the descriptions and messages of the rules contain references to constants defined in this document. It is required that when the errors/warnings are reported to users the references to these constants are replated with their numerical value and unit. For instance, if the message contains "… is not >= EQ_BRANCH_X_LIMIT for a two-winding transformer … " the validation engine shall report to the user "… is not >= 0.01 Ohm for a two-winding transformer … "
4) In cases where messages provided by a validation engine shall be further processed in a reporting system, the reporting system shall either use reported numbers with the same number of decimals or apply arithmetical rounding, if necessary.
5) When comparing values with PEVF and CGMA it should be taken into account that:
    - There is no sign convention in PEVF and CGMES as all values are positive and there are different properties for "in domain" and "out domain", which provide flow direction.
    - Net Position means the netted sum of electricity exports and imports for each market time unit for a scheduling zone.
    - If "in domain" is the TSO and "out domain" is the synchronous area, it means an import to the TSO area
    - If "in domain" is the synchronous area and "out domain" is the TSO, it means an export from the TSO area
    - For QAR report and QAS portal, the import is represented by a negative value and the export by a positive value.
6) Validation engines shall consider that:
    - In many cases an IGM has multiple cim:TopologicalIsland-s. In the cases where an IGM contains multiple cim:TopologicalIsland-s, the island that contains the highest number of associated cim:TopologicalNode-s shall be referred to as main island. While the validation rules related to load-flow plausibility and convergency status are

executed for all islands in an IGM, the status of the main island, “converged” or “diverged”, shall define the overall status of an IGM.

- The CGM is Pan-European, therefore containing multiple synchronous areas and potentially, in case of partial merge, not all IGMs of the synchronous area. Therefore, one more level of grouping is necessary for a CGM. The main island in CGM shall be defined as the cim:TopologicalIsland containing the highest number of IGMs. The number of IGMs in a cim:TopologicalIsland is calculated using the associated cim:TopologicalNode-s affiliated to each IGM part of a cim:TopologicalIsland. The status of the main island, “converged” or “diverged”, shall define the overall status of a CGM.

3 LEVEL 1 VALIDATION: META DATA IN FILE NAMES

3.1 INTRODUCTION

According to IEC 61970-600-1:2017 (Common Grid Model Exchange Specification 2.4), rule FILX2, “There is no naming convention applied to the .xml or .zip file names. Although different business processes may define such a file naming convention, the applications shall rely solely on the information provided in the file headers in order to process the instance files.”

It was agreed in the 38th SOC meeting on 5 November 2015 that business processes related to the operational planning shall use a file naming convention. This section defines such name convention which is applied for Individual Grid Models and Common Grid Models exchanged in CGMES. The file names are primarily used for human consumption but are also used for validating file header content and for the storing of meta data in the OPDM. This meta data is used in OPDM for filtering and manually collecting data via the OPDM user interface

As the file names contain information about file type, effective dates and version which is also specified in the file headers, this data needs to be consistent. This is validated in level 2. Meta data is specified both in the file header and the file name. Meta data in the file header FullModel element as described below:

- Modeling Authority (i.e. the name of the TSO or RSC) is included in the Model.modelingAuthoritySet attribute.
- If a Modeling Authority has more than one network region a region specifier is included in the Model.modelingAuthoritySet attribute (further described below).
- The Model.description attribute contains several meta data items, refer to level 2 rule ModelDescription.
- HVDC boundary TopologicalNodes has “HVDC” as the first characters in the IdentifiedObject.description.

Several meta data are embedded as enumerations in the rules. This reference data is defined in the document QoCDC Reference Data. Therefore, when reference data is modified the QoCDC Reference Data document will be updated accordingly.

3.2 FILE NAME AND FILE HEADER

The CIMXML file name convention specifies the meta data parts of the file name, separated by an underscore ('_') and applies to both the xml name and the zip name.

Rule FILX1 in IEC TS 61970-600-1:2017 specifies that "a given exchange consists of multiple files. The CGMES defines that all files in a given logical exchange must be zipped together. The tools use zip files directly when importing and exporting, but some business process may require the files to be exchanged in individual zip files". This is the case for the Common Grid Model building process.

The following mask is to be used to have a valid file name:

<effectiveDateTime>_<businessProcess>_<sourcingActor>_<modelPart>_<fileVersion>

The following additional rules applies for IGM and CGM file names with this mask:

- The parts in the file name are not allowed to contain an underscores "_" or dashes "-". The dashes are reserved for sub parts within the sourcingActor.
- All four underscores shall be present.
- If a file name part is not used it shall be left empty resulting in two consecutive underscores "__".
- For <modelPart> SSH, TP and SV all five parts in the mask shall be present.
- For <modelPart> EQ and EQDIFF the <businessProcess> may be absent meaning that the CIMXMLfile can be used with any business process. The mask to use is then
    - <effectiveDateTime>__<sourcingActor>_<modelPart>_<fileVersion>

The <sourcingActor> field has three different layouts:

1. <sourcingTSO> which is always used by a TSO
2. <sourcingRSC>-<cgmRegion> which is used by RSC for a synchronous area file, e.g. a SV file
3. <sourcingRSC>-<cgmRegion>-<sourcingTSO> which is used by RSC for an updated TSO area file, e.g. a SSH file. The sourcingTSO relates to the IGM that has been used to create the CGM.

The mapping of <sourcingTSO>, <sourcingRSC> and <cgmRegion> to the reference data is provided in the QoCDC Reference Data document in the tab "QoCDC Mapping".

Examples:

- 20180118T0930Z_1D_APG_SSH_001.xml
- 20180117T2230Z_1D_APG_EQ_001.xml
- 20180117T2230Z__APG_EQ_001.xml
- 20180118T1130Z_1D_TSCNET-CE_SV_001.xml
- 20180118T1130Z_1D_TSCNET-CE-APG_SSH_001.xml

The following mask is allowed for boundary files:

<effectiveDateTime>__<sourcingActor>_<modelPart>_<fileVersion>

The following additional rules apply for the boundary set file names mask:

- sourcingActor shall be ENTSOE.
- None of the parts in the file name are allowed to contain an underscore "_" or dash "-".
- All four file name parts shall be present.
- The number of underscores in a file name is always four.

Examples:

- 20180226T0000Z__ENTSOE_EQBD_101.xml

The effectiveDateTime is the same as the md:Model.scenarioTime in the md:FullModel header.

Each SSH, TP and SV CIMXML file are valid for specific effectiveDateTime. The effectiveDateTime is defined based on the CGMM-v3[4], for example in case of day-ahead process in Article 4(2) as "…each TSO shall build a day-ahead IGM for each market time unit of the day of delivery. The mid-point of each market time unit shall be used as the reference timestamp." So, for day-ahead IGM, the SSH, TP and SV CIMXML file is valid for a market time unit of one hour, and the reference timestamp is mid-point of an hour (HH:30, HH indicating an hour in UTC notation) represented by effectiveDateTime as YYYYMMDDT**HH30**Z.

EQ, EQDIFF, EQBD and TPBD CIMXML files do not require every hour creation and are valid starting from provided effectiveDateTime until the new EQ or EQDIFF with one of the succeeding effectiveDateTime is provided.

EQ and EQDIFF CIMXML files are to maintain the same reference timestamp being mid-point of market time unit meaning mid-point of an hour, effectiveDateTime being YYYYMMDDT**HH30**Z.

EQBD and TPBD CIMXML files are created with YYYYMMDDT**0000**Z effectiveDateTime, for both of the CIMXML files as well as the zipped package of those two.

The fileVersion is exactly three characters long positive integer number between 000 and 999, i.e. the first positive integer is 001 and the last 999.

The allowed values for "ModelingAuthority" and "ModelingAuthority URI" are defined in the QoCDC Reference Data document. The tab "QoCDC Mapping" provides the mapping between the reference data and QoCDC notations.

TSO network regions are combined into larger networks called synchronous areas described in the QoCDC Reference Data document. CGMRegions consists of GeographicalRegions or SubGeographicalRegions. For instance, Energinet has one GeographicalRegion and two SubGeographicalRegions (DKW and DKE) in different CGMRegions. Hence DKW and DKE SubGeographicalRegions are included in the QoCDC Reference Data document. If a TSO has HVDC links, they are treated as their own SubGeographicalRegions that are also included in the QoCDC Reference Data document.

The file name templates have proved to create non-unique file names and have been frequently revised due to this. The templates also require reserved characters, underscore (_) and dash (-) to

[4] https://docstore.entsoe.eu/Documents/Network%20codes%20documents/Implementation/cacm/cgmm/CGMM-v3.pdf

guide parsing the meta data from the file name string. Hence these characters are not allowed in the meta data fields. As the file name templates are not future proof it is advised not to use them in other business processes than covered by this document.

3.2.1 MD:MODEL.DESCRIPTION

The attribute md:Model.description is declared as a string which means it shall be serialised as valid string.

The content of md:Model.description and its sub-elements is defined as follows:

- there is no specific namespace for the elements of the structure;
- MDE field is required;
- BP field is required. It is indicating the business process from level 1 rule BusinessProcess;
- TOOL field is required. It is indicating tool name and version number;
- RSC field is optional for IGM and required for SV and SSH that are created and serialised by a RSC;
- TXT field is optional free text.

Based on this requirement the following XML structure is obtained:

```
<MDE>
  <BP>1D</BP>
  <TOOL>PowerFactory 2021</TOOL>
  <RSC>N/A</RSC>
  <TXT>QoCDC v3.2 test configuration</TXT>
</MDE>
```

As the XML structure shall be serialized as string representing an escaped character xml structure, the content of md:Model.description for the above structure shall be:

<md:Model.description><MDE><BP>1D</BP><TOOL>PowerFactory 2021</TOOL><RSC>N/A</RSC><TXT>QoCDC v3.2 test configuration</TXT></MDE> </md:Model.description>

3.3 VALIDATION RULES

```
Rule: FileNameMD  Level: 1  Severity: ERROR

      Details:
      Two different file name templates are used:
      1) effectiveDateTime_businessProcess_sourcingActor_modelPart_fileVersion
      2) effectiveDateTime__sourcingActor_modelPart_fileVersion
      The templates have fields separated by four underscores (_).
```

```
651         Depending on the modelPart field (allowed values are listed in rule ModelPartType)
652         the usage of above templates is as follows:
653         - EQ shall use both template 1 and 2;
654         - SSH, TP and SV shall only use template 1;
655         - EQBD and TPBD shall only use template 2.
656
657         The field sourcingActor has sub-fields separated by dashes (-). The following three
658         sub-templates are allowed for sourcingActor field:
659         - sourcingTSO, which is always used by a TSO;
660         - sourcingRSC-cgmRegion, which is used by RSC for a synchronous area file, e.g. a
661         SV file;
662         - sourcingRSC-cgmRegion-sourcingTSO, which is used by RSC for an updated TSO area
663         file, e.g. a SSH file.
664
665         Note that model parts such as DL, DY, GL are not included as they are not in the
666         implementation scope of QoCDC.
667
668         Justification:
669
670         Message:
671         Number of meta data fields in file name does not match the rules.
672
673         Usage: #IGMRuleSet #CGMRuleSet
674
675   Rule: FileNameConsistency  Level: 1  Severity: ERROR
676
677         Details:
678         Each cimxml file (including EQBD and TPBD) is contained by a single zip container.
679         The file name of the cimxml file within the container must be the same as the name
680         of the container. However, EQBD and TPBD might be zipped together in case they need
681         to be uploaded in OPDE, which is an implementation detail.
682
683         Justification:
684
685         Message:
686         XML instance file name is different from zip container file name.
687
688         Usage: #IGMRuleSet #CGMRuleSet
689
690   Rule: EffectiveDateTime  Level: 1  Severity: ERROR
691
692         Details:
693         The 'effectiveDateTime' in the file name must be a valid datetime
694         in minute resolution in accordance with ISO 8601-2005, basic format
695         with time designator [T] between date and time and ending with
696         UTC designator [Z]. For example, 20180118T1130Z.
697         The restriction describes the minimum required specification that a
698         receiver shall be prepared to consume. A more precisely specified
699         time defined by characters [:-+YMDHSWP] will be ignored.
700
701         Justification:
702         The relevant time resolution for the business process is minute level and
703         the time in the file name shall match with this attribute.
704
705         Message:
706         EffectiveDateTime in file name is invalid.
```

```
707
708         Usage: #IGMRuleSet #CGMRuleSet
709
710   Rule: SourcingActor  Level: 1  Severity: ERROR
711
712         Details:
713         The sourcingActor, that appears in the cimxml file name, is composed as described
714         in rule FileNameMD. The choice on sourcingActor is made by the responsible TSO and
715         it is recorded in the QoCDC Reference Data document.     Once     decided     the
716         sourcingActor should comply with the defined names in the QoCDC Reference Data
717         document.
718
719         Justification:
720         The sourcingActor shall comply with the choices made by a TSO.
721
722         Message:
723         Undefined TSO or network region names specified.
724
725         Usage: #IGMRuleSet #CGMRuleSet
726
727   Rule: CGMRegion  Level: 1  Severity: ERROR
728
729         Details:
730         TSO networks are organized in synchronous areas including
731         multiple TSO network regions. Each synchronous area is
732         assigned unique identifiers in file names.
733         The allowed synchronous areas are listed in the
734         QoCDC Reference Data document.
735
736         Justification:
737         Needed to uniquely identify synchronous areas for SV of CGM.
738
739         Message:
740         Unidentified synchronous area specified in SV instance filename of CGM.
741
742         Usage: #CGMRuleSet
743
744   Rule: BusinessProcess  Level: 1  Severity: ERROR
745
746         Details:
747         The 'businessProcess' in the file name is restricted according
748         to a list in the QoCDC Reference Data document.
749         See also level 2 rule ModelDescription where the BusinessProcess
750         is required in the Model.description attribute.
751
752         Justification:
753
754         Message:
755         Unknown business process.
756
757         Usage: #IGMRuleSet #CGMRuleSet
758
759
760   Rule: ModelPartType  Level: 1  Severity: ERROR
761
762         Details:
```

```
763         The 'modelPart' in the file name is restricted.
764         Note that the profile declarations in the file header are
765         leading and shall be used as meta data to request data.
766
767         The allowed model part types are as follows: DL, DY, EQ, EQBD, EQDIFF, GL, SSH,
768         SV, TP, TPBD.
769
770         Justification:
771
772         Message:
773         Unknown modelPart type in the filename.
774
775         Usage: #IGMRuleSet #CGMRuleSet
776
777
778   Rule: FileVersionType  Level: 1  Severity: ERROR
779
780         Details:
781         The 'fileVersion' in the file name must be positive integer value always
782         represented by three numeric characters ranging from 000 to 999, i.e. the first
783         positive integer is 001 and the last 999.
784         Leading zeros are allowed.
785
786         Justification:
787         See this specification section 3.1 and IEC TS 61970-600-1 C.3.1.
788
789         Message:
790         File version must be a number with three numeric character positions.
791
792         Usage: #IGMRuleSet #CGMRuleSet
```

793 4 LEVEL 2 VALIDATION: STRUCTURE SYNTAX AND METADATA

794 4.1 INTRODUCTION

795 CGMES data is exchanged as CIM RDF[5] XML[6] files. The Resource Description Framework uses an
796 XML based syntax, allowing relationships to be defined between XML nodes. The first level of syntax
797 validation is to check if the document is well formed in accordance with the XML rules[7].

798 RDF syntax provides many ways to represent the same set of data. For example, an association
799 between two resources can be written with a resource attribute or by nesting one element within
800 another. This could make it difficult to use some XML tools, such as XSLT processors, with the
801 CIMXML document.

---

[5] Resource Description Framework, i.e. a language recommended by the W3C for expressing meta data that machines can process easily

[6] eXtensible Markup Language, i.e. a subset of the Standard Generalized Markup Language (SGML), ISO 8879, for putting structured data in a text file

[7] The full set is specified in the W3C Recommendation, “Extensible Markup Language: Prolog and Document Type Declaration” Version 1.0, 26 November 2008, available at http://www.w3.org/TR/REC-xml/#sec-prolog-dtd

Therefore, only a subset of the RDF Syntax is to be applied in creating CIMXML documents. This syntax simplifies the work of implementers to construct model serialization and deserialization software, as well as to improve the effectiveness of general XML tools when used with CIMXML documents. The reduced syntax is a proper subset of the standard RDF syntax; thus, it can be read by available RDF de-serialization software.

The simplified syntax is for exchanging power system models between utilities. The aim of the IEC 61970-552:2013 (Edition 1.0) specification is to make it easier for implementers to construct de-serialization software for RDF data, to simplify their choices when serializing RDF data, and to improve the effectiveness of general XML tools such as XSLT processors when used with the serialized RDF data.

The reduced syntax does not sacrifice any of the power of the RDF data model. That is, any RDF data can be exchanged using this syntax. Moreover, features of RDF such as the ability to extend a model defined in one document with statements in second document are preserved.

Errors in XML documents will stop XML applications. The W3C XML specification states that a program should stop processing an XML document if it finds an error. The reason is that XML software should be small, fast, and compatible. HTML browsers are allowed to display HTML documents with errors (like missing end tags). With XML, errors are not allowed.

The CGMES files shall have an XML prolog that declares the version of the XML and in which the encoding is set to UTF-8 (acc. to CENC10 in IEC TS 61970-600-1:2017). Missing encoding is considered an erroneous file.

It shall be possible to trace back the error detected by the validating processor, specifying the file name, error detected and line number in the file.

4.2 RDF SCHEMA

CGMES data is exchanged as CIMXML files, as specified in IEC 61970-552:2013 (Edition 1.0). The older ID formats according to section 6.4 is allowed.

RDFS files, generated from the UML, describe the CGMES profile classes, attributes and roles with cardinalities using an extended RDFS notation described in IEC 61970-501 Ed1.

The RDFS files can be downloaded from the ENTSO-E website. The Resource Description Framework supports extensibility, meaning that classes attributes or roles not used in the CGMES profiles still can be exchanged in CIMXML files. Hence it is allowed for a creator of a CIMXML file to include any information not in the CGMES profiles. However, a receiver of such a CIMXML file will only read the information described by the CGMES profiles defined for the exchange. Hence a creator of a CIMXML with additional information cannot expect a receiver to process the data not described in the CGMES profiles.

The following table specifies which RDFS file is to be used for validation.

Table 3 RDF schema descriptions

ModelProfile value	RDF schema description
http://entsoe.eu/CIM/EquipmentBoundary/3/1	EquipmentBoundaryProfileRDFSAugmented-v2_4_15-16Feb2016.rdf

http://entsoe.eu/CIM/TopologyBoundary/3/1	TopologyBoundaryProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1	EquipmentProfileCoreRDFSAugmented-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1 **http://entsoe.eu/CIM/EquipmentOperation/3/1**	EquipmentProfileCoreOperationRDFSAugmented-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1 **http://entsoe.eu/CIM/EquipmentShortCircuit/3/1**	EquipmentProfileCoreShortCircuitRDFSAugmented-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/EquipmentCore/3/1 **http://entsoe.eu/CIM/EquipmentOperation/3/1** **http://entsoe.eu/CIM/EquipmentShortCircuit/3/1**	EquipmentProfileCoreShortCircuitOperationRDFSAugmented-v2_4_15-4Jul2016.rdf
http://entsoe.eu/CIM/SteadyStateHypothesis/1/1	SteadyStateHypothesisProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/Topology/4/1	TopologyProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/StateVariables/4/1	StateVariablesProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/DiagramLayout/3/1	DiagramLayoutProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/GeographicalLocation/2/1	GeographicalLocationProfileRDFSAugmented-v2_4_15-16Feb2016.rdf
http://entsoe.eu/CIM/Dynamics/3/1	DynamicsProfileRDFSAugmented-v2_4_15-16Feb2016.rdf

Any tool implementing the CGMES profile shall check CIMXML data and verifying that

- Class, attribute and role names appearing in a file is defined by the profile.
- Cardinality constraints are respected.

The rules “NotMandatoryClass” or “NotMandatoryProperty” are used to warn about classes, attributes and roles not described by CGMES profiles.

With the class cardinality it is possible to describe if instances of a particular class are required but this feature has not been used. Instead, rules have been created specifying the number of required instances, e.g. the rule “ControlAreaInstance” that requires exactly one instance of the ControlArea class in an IGM. In UML it is possible to specify this as the cardinality on a class, but this capability hasn’t been used for CGMES.

For the attributes and roles, the cardinality value specifies how many times an attribute value or role reference shall appear in a CIMXML file. The rule “IncorrectAttributeOrRoleCard” reports violated cardinality.

4.3 METADATA

The Model header from IEC 61970-552 is validated and cross checked with the meta data in the file name if present in both places.

4.4 VALIDATION RULES

```
Rule: Prolog  Level: 2  Severity: ERROR

      Details:
      The CIMXML file must have a prolog containing attributes
      version and encoding.

      Justification:
      See this specification, section 4.1.

      Message:
```

```
        Prolog is missing.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: Encoding  Level: 2  Severity: ERROR

        Details:
        If the encoding is different from UTF-8, it shall be considered an error
        Note: the encoding is case insensitive

        Justification:
        See IEC TS 61970-600-1:2017 GENC10.

        Message:
        Missing encoding or encoding other than UTF-8.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: XMLStructure  Level: 2  Severity: ERROR

        Details:
        If the XML parsing fails, the process is aborted.

        Justification:
        https://www.w3.org/TR/REC-xml/#dt-fatal

        Message:
        XML parsing error.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: FileHeader  Level: 2  Severity: ERROR

        Details:
        Each type of instance file shall have exactly one file header of type
        FullModel or DifferenceModel.

        Justification:
        Requirement HGEN2 of IEC TS 61970-600-1:2017, IEC 61970-552, section 5.2.

        Message:
        Missing file header.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: URNUniqueness  Level: 2  Severity: ERROR

        Details:
        A new model ID shall be generated for new instance files, only when
        the content of the instance data changes. A new version means a new URN.
        This is a process related rule and cannot be validated in standalone model of
validation of an IGM.

        Justification:
        Requirement HREF1, HREF5 of IEC TS 61970-600-1:2017.
```

Message:
URN of the instance file already exists.

Usage: #IGMRuleSet #CGMRuleSet

Rule: MAS Level: 2 Severity: ERROR

Details:
1) md:Model.modelingAuthoritySet is required in the header of all instance files.
2) md:Model.modelingAuthoritySet shall have one of the values specified in the QoCDC Reference Data document.
3) md:Model.modelingAuthoritySet of a CGM SV instance file shall be the MAS that creates the state variables. The value of md:Model.modelingAuthoritySet is not validated against QoCDC Reference Data document, but it is recommended to be constructed as follows: MA/Region/Process, where
   - MA is the URI of the MergingAgent
   - Region is the name of the CGMRegion
   - Process is the name of the ProcessType.

Note: This rule intentionally overrides MAPR10 and MARP11 of IEC TS 61970-600-1:2017.

Justification:
Requirement HGEN1 IEC TS 61970-600-1:2017.
The attribute is mandatory for the CGM process.

Message:
Missing or invalid md:Model.modelingAuthoritySet specification.

Usage: #IGMRuleSet #CGMRuleSet

Rule: MASPersistency Level: 2 Severity: ERROR

Details:
The rule applies for IGM only. The 'md:Model.modelingAuthoritySet' attribute must be persistent for all CIMXML files of an IGM.
Note that to test this across CIMXML files this must be done for a model where all files have been included.

Justification:
See this document section 3.1 and IEC TS 61970-600-1 table in C.3.1.

Message:
md:Model.modelingAuthoritySet is not persistent across IGM files.

Usage: #IGMRuleSet

Rule: ModelCreated Level: 2 Severity: ERROR

Details:
The date and time when the model was created.
It is the time of the serialization.
The format is an extended format according to the ISO 8601-2005.

```
975         The ENTSO-E exchanges should refer to UTC.
976         The 'md:Model.created' attribute must be valid datetime in accordance
977         with ISO 8601, extended format with time designator [T] between date
978         and time ending with UTC designator [Z]. The characters [:-] shall be used. For
979         example, 2018-01-18T11:30:12Z or 2018-01-18T11:30:12.015Z.
980
981         The restriction describes the minimum required specification that a
982         receiver shall be prepared to consume. A more precisely specified
983         time defined by characters [+YMDHSWP] will be ignored.
984
985         Justification:
986         Annex C of IEC TS 61970-600-1:2017.
987
988         Message:
989         Invalid Model.created attribute.
990
991         Usage: #IGMRuleSet #CGMRuleSet
992
993   Rule: ScenarioTime  Level: 2  Severity: ERROR
994
995         Details:
996         The 'md:Model.scenarioTime' attribute must be valid datetime in
997         accordance with ISO 8601, extended format with time designator [T]
998         between date and time ending with UTC designator [Z].
999         The characters [:-] shall be used. For example, 2018-01-18T11:30:00Z, 2018-01-
1000        18T11:30:12.000Z or 2018-01-18T11:30Z.
1001
1002        The restriction describes the minimum required specification that a
1003        receiver shall be prepared to consume. A more precisely specified
1004        time defined by characters [+YMDHSWP] will be ignored.
1005
1006        Justification:
1007        Annex C of IEC TS 61970-600-1:2017.
1008
1009        Message:
1010        Invalid Model.scenarioTime attribute.
1011
1012        Usage: #IGMRuleSet #CGMRuleSet
1013
1014  Rule: ScenarioTimeConsistency  Level: 2  Severity: ERROR
1015
1016        Details:
1017        The 'md:Model.scenarioTime' attribute shall refer to the same datetime
1018        as the 'effectiveDateTime' in the file name, considering minute
1019        resolution.
1020
1021        Justification:
1022        Necessary to produce consistent meta data for the exchange process.
1023
1024        Message:
1025        The scenarioTime specification in the file header does not match the
1026        effectiveDateTime specified in the file name.
1027
1028        Usage: #IGMRuleSet #CGMRuleSet
1029
1030  Rule: VersionConsistency  Level: 2  Severity: ERROR
```

```
1031
1032          Details:
1033          The 'md:Model.version' attribute shall be the same number
1034          as the 'fileVersion' string from the file name converted to an integer.
1035
1036          Justification:
1037          Necessary to produce consistent meta data for the exchange process.
1038
1039          Message:
1040          The model version does not match the file version.
1041
1042          Usage: #IGMRuleSet #CGMRuleSet
1043
1044    Rule: ProfileSpecification  Level: 2  Severity: ERROR
1045
1046          Details:
1047          The 'md:Model.profile' description in the file header is restricted.
1048          Note: The profile declarations in the file header are leading and
1049          shall be used as meta data to request data.
1050          The enumeration values are centrally maintained in
1051          QoCDC Reference Data document.
1052
1053          Justification:
1054          Necessary to determine which RDFS rules to use.
1055          Requirement FBOD2, HGEN1 of IEC TS 61970-600-1:2017
1056          Annex C of IEC/TS 61970-600-1:2017.
1057
1058          Message:
1059          Invalid profile specification.
1060
1061          Usage: #IGMRuleSet #CGMRuleSet
1062
1063
1064    Rule: ModelDescription  Level: 2  Severity: WARNING
1065
1066          Details:
1067          The md:Model.description attribute is required and shall contain the xml structure
1068          that is described in section 3.2.1. The xml structure shall be serialised in the
1069          attribute as escaped XML, i.e. still as a string.
1070
1071          Justification:
1072          See this specification section 3.2.1.
1073
1074          Message:
1075          md:Model.description is not provided or does not contain required fields.
1076
1077          Usage: #IGMRuleSet #CGMRuleSet
1078
1079    Rule: NotMandatoryClass  Level: 2  Severity: WARNING
1080
1081          Details:
1082          An instance of a class not described in a CGMES
1083          profile is ignored and reported.
1084          If an importing tool requires a class not described in a CGMES
1085          profile issues may occur for a CGM where other IGMs do not contain
1086          instances of the class.
```

Justification:
Requirement PROF11 of IEC/TS 61970-600-1:2017.

Message:
Class instance in cimxml document is ignored.

Usage: #IGMRuleSet #CGMRuleSet

Rule: NotMandatoryProperty Level: 2 Severity: WARNING

Details:
A role or attribute not described in a CGMES profile is ignored and reported. If an importing tool require a role or attribute not described in a CGMES profile issues may occur for a CGM where other IGMs do not contain instances of the role or attribute.

Justification:
Requirement PROF11 of IEC/TS 61970-600-1:2017.

Message:
Role or attribute in cimxml document is ignored.

Usage: #IGMRuleSet #CGMRuleSet

Rule: AttributeAndRoleValues Level: 2 Severity: ERROR

Details:
Attribute and role values appearing in a CIMXML document shall have a value. The rule checks empty attributes that are not of type String.

Notes:
- Example of empty attribute: [cim:class.attribute/] or [cim:class.attribute][/cim:class.attribute]
- Example of empty rdf:resource [cim:class.attribute rdf:resouce=""/], note this is not a valid reference and it is part of rule XMLStructure.

Note: the xml angle brackets has been replaced by square parenthesis in above examples.

Justification:
Only meaningful data shall be exchanged in CIMXML documents.
See also IEC TS 61970-600-1 NAMC14.

Message:
Empty attribute or rdf:resource is present.

Usage: #IGMRuleSet #CGMRuleSet

Rule: ValidResourceValue Level: 2 Severity: ERROR

Details:
For all rdf:resource except the references to enumerations, the value of rdf:resource shall start with '#_' or 'urn:uuid:'. The 'urn:uuid:' form is used in the md:Model.Supersedes and md:Model.DependentOn references.

```
        Justification:
        See IEC 61970-552.

        Message:
        Invalid reference, rdf:resource.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: ValidAboutValue  Level: 2  Severity: ERROR

        Details:
        If '#_' or 'urn:uuid:' do not prefix the value of rdf:about, the mRID
        is invalid. The 'urn:uuid:' form is used in the object definition
        attribute md:FullModel rdf:about.

        Justification:
        See IEC 61970-552.

        Message:
        Invalid mRID rdf:about.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: ValidIDValue  Level: 2  Severity: ERROR

        Details:
        If '_' do not prefix the value of rdf:ID, the mRID is invalid.

        Justification:
        See IEC 61970-552.

        Message:
        Invalid mRID.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: DecimalComma  Level: 2  Severity: ERROR

        Details:
        Decimal comma is not allowed in floating point numbers.
        Shall be decimal point.

        Justification:
        IEEE 754.
        Note: A locale settings may select either comma or full stop and a particular
        locale settings do not support both comma and full stop. Due to this a mix of
        comma and full stop prevent interoperability, hence one must be selected.

        Message:
        Decimal comma is not allowed in floating point numbers.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: NotaNumber  Level: 2  Severity: ERROR

        Details:
```

```
If data is missing for a CIM/CGMES attribute, or if 'NaN', 'INF' or
'-nan(ind)' etc. is used when a numeric value is expected, the model
is considered erroneous.
If a code is allowed for a numeric value this shall be specifically stated
for that attribute.

Justification:
Not a Number values cannot be processed correctly.

Message:
No valid value provided.

Usage: #IGMRuleSet #CGMRuleSet
```

5 LEVEL 3 VALIDATION: CONSTRAINTS AND MAPPING

5.1 CONSTRAINTS FOR NAMING ATTRIBUTES

IEC TS 61970-600-1:2017, Annex B, specifies the maximum length of naming attributes for IdentifiedObject classes in all profile instance files and for ConnectivityNodes and TopologicalNodes in Boundary instance files.

5.2 CONTAINMENT RULES

Equipment containers represent ways of organizing and naming equipment typically found within a substation. As may be seen, there is some flexibility provided in which containers are used in a specific application of the CIM in order to accommodate different international practices as well as differences typically found between transmission and distribution substations. Bay, VoltageLevel, Substation, Line, DCLine and DCConverterUnit are all types of EquipmentContainer. In general, a Bay is contained within a specific VoltageLevel, which in turn is contained within a Substation. Substations and Lines may be contained within a SubGeographicalRegion and as a consequence within a GeographicalRegion.

One containment hierarchy is used with the IdentifiedObject class to create hierarchical naming intended for human consumption. This hierarchy is specifically used to name equipment according to its function in the power system. This is called the functional naming hierarchy. Containment is defined in Equipment instance files and in Equipment Boundary instance files.

5.3 CONSTRAINTS DEFINED BY CGMES

The IEC TS 61970-600-2 specifies additional constraints to the attribute values, conditional associations and enumerations.

5.4 CONSTRAINTS DEFINED BY BEST PRACTICES

This paragraph specifies a number of equipment modelling business rules that have their origin from best practices and common sense in Power Flow calculations. Rationales and justifications are provided in the rules.

5.4.1 LIMIT VALUES

Limit values for a synchronous machine are defined by reactive capability curves that define the limits at a specific operating voltage. Note that CIM/CGMES only allows for one reactive capability

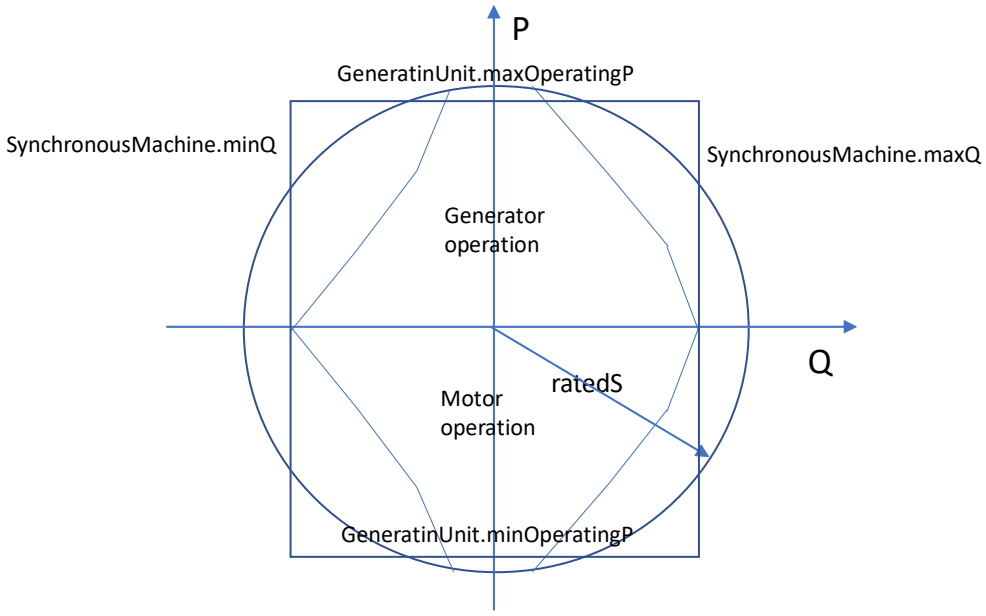

Figure 3 Example Reactive Capability Curve

A reactive capability curve has both active and reactive power limits.

In case the limits are not specified with a reactive capability curve constant limit values are available as follows:

- maxOperatingP and minOperatingP at the cim:GeneratingUnit class;
- maxQ and minQ at the cim:SynchronousMachine. Note that maxQ and minQ are optional attributes which are required if there is no ReactivecapabilityCurve associatied with the machine.

In Figure 3 those four constant limits are shown as a box.

A synchronous machine can be used as condenser, generator, motor (typically a pump in power systems) or a mix of them. The attribute cim:SynchronousMachine.type defines the supported mix

of usages and the attribute cim:SynchronousMachine.operatingMode defines the operating mode used at the operating state represented by SSH. This results in a complex relation between

- cim:SynchronousMachine.type,
- cim:SynchronousMachine.operatingMode, and
- the four limit values.

The following three cases represent combinations for generator and motor. Note that condenser type is not included as it has no GeneratingUnit associated and it cannot be used for the purpose of generating active power.

1. An as built generator shall have positive active power limits and can only operate as a generator, see Figure 4.
2. An as built motor shall have negative active power limits and can only operate as a motor, see Figure 5.
3. An as built generator and motor can operate either in generator operating mode or in motor operating mode, see Figure 3, and shall have
    - a positive maxOperatingP, and
    - a negative minOperatingP.

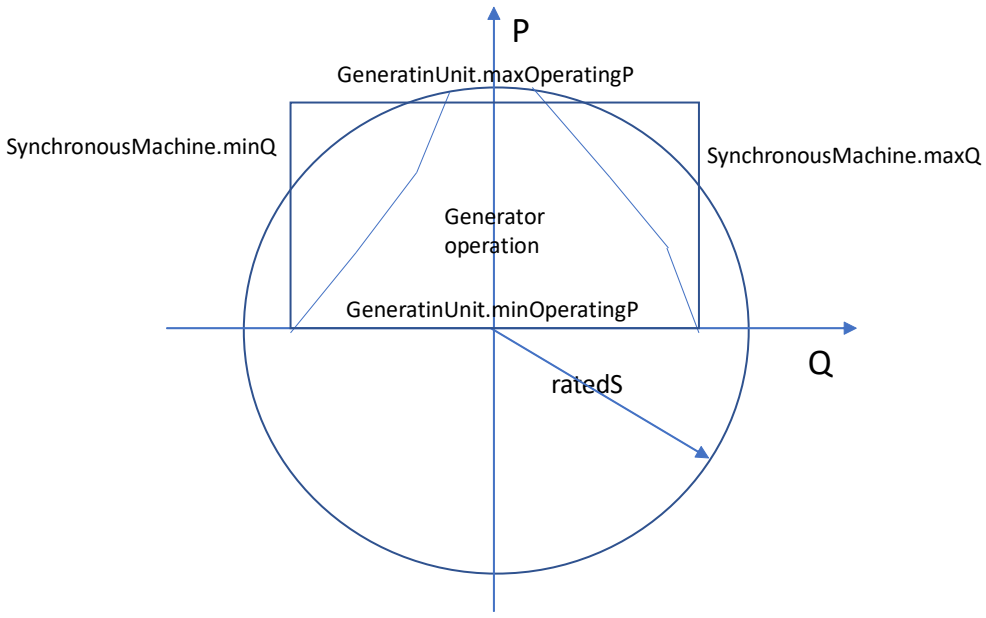

Figure 4 Generator only

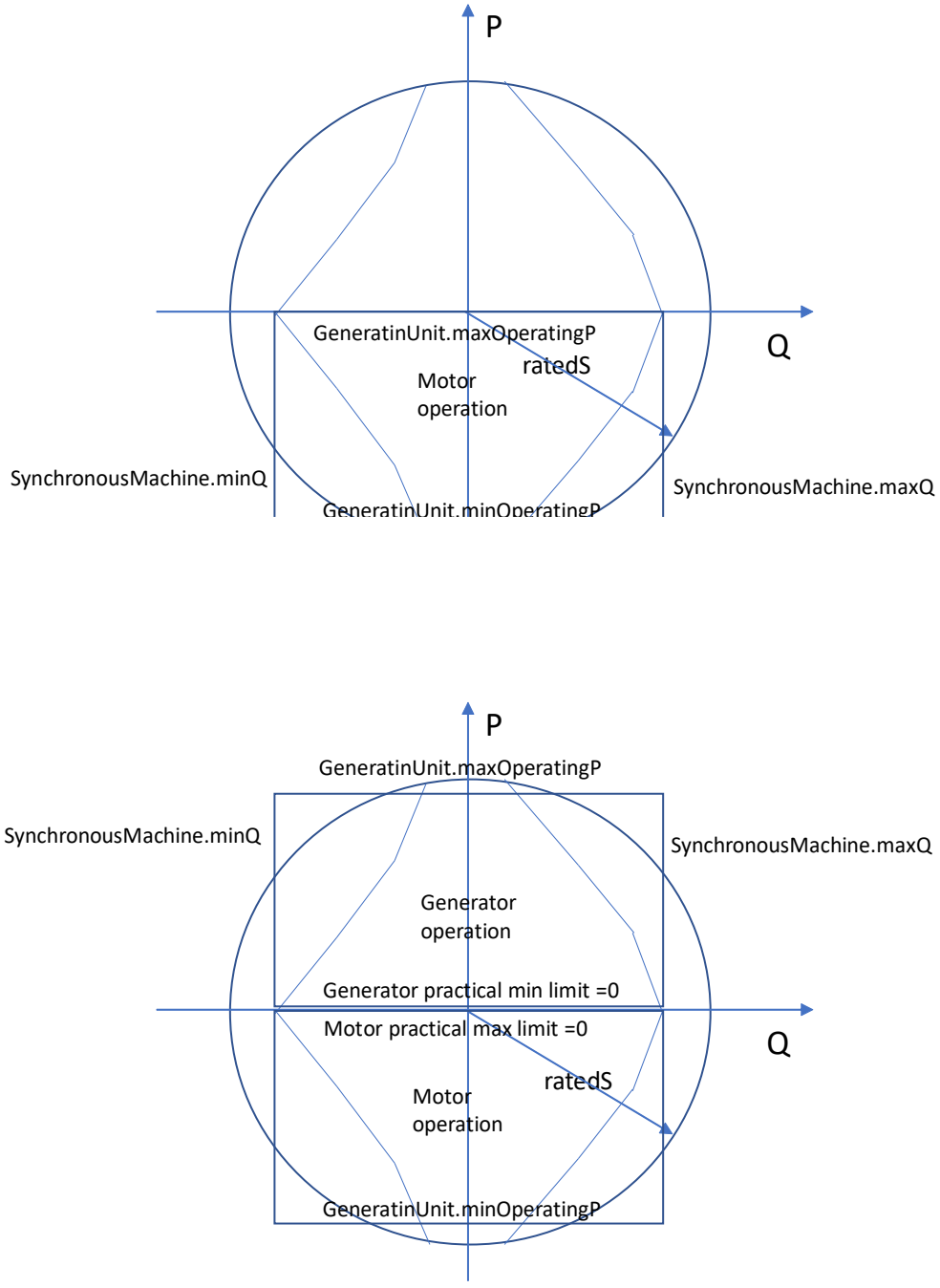

Figure 6 Generator or motor operation

5.5 MAPPING REQUIREMENTS DEFINED BY CGM CONTEXT

The quality checks in this section refer to information that is required to be able to use scheduled and aligned netted area AC positions and target flows on HVDC links as set points in the CGM process.

5.6 VALIDATION RULES

Rule: NameLength Level: 3 Severity: ERROR

Details:
In cases where cim:IdentifiedObject.name is a required attribute, it shall not be empty string and shall not exceed IO_NAME_LENGTH characters for all instances except for instances of subclasses of cim:ACDCTerminal where cim:IdentifiedObject.name may be omitted.

Note: This rule further restricts IEC TS 61970-600-1:2017, IEC TS 61970-600-2:2017 where empty strings are allowed in cim:IdentifiedObject.name.

Justification:
See IEC TS 61970-600-1:2017 B.1.

Message:
cim:IdentifiedObject.name is either missing, empty string or exceeds IO_NAME_LENGTH characters.

Usage: #IGMRuleSet #CGMRuleSet

Rule: DescriptionLength Level: 3 Severity: ERROR

Details:
In every model instance, the length of all instances of cim:IdentifiedObject.description shall not exceed IO_DESCRIPTION_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.2.

Message:
Length of description instance exceeds IO_DESCRIPTION_LENGTH characters.

Usage: #IGMRuleSet #CGMRuleSet

Rule: EICLength Level: 3 Severity: ERROR

Details:
In every model instance, the length of all instances of entsoe:IdentifiedObject.energyIdentCodeEic must be exactly EIC_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.3.

Message:
Length of energyIdentCodeEic instance must be exactly EIC_LENGTH characters.

Usage: #IGMRuleSet #CGMRuleSet

Rule: ShortNameLength Level: 3 Severity: ERROR

Details:

```
        In every model instance, the length of all instances of
        entsoe:IdentifiedObject.shortName shall not exceed
        SHORT_NAME_LENGTH characters.

        Justification:
        See IEC TS 61970-600-1:2017 B.4.

        Message:
        Length of shortName instance exceeds SHORT_NAME_LENGTH characters.

        Usage: #IGMRuleSet #CGMRuleSet

Rule: CNFromEndIsoCode  Level: 3  Severity: ERROR

        Details:
        In an EQBD document attribute value entsoe:ConnectivityNode.fromEndIsoCode
        must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.

        Justification:
        See IEC TS 61970-600-1:2017 B.5.

        Message:
        Country code used that is not in the reference data.

        Usage: #IGMRuleSet


Rule: TNFromEndIsoCode  Level: 3  Severity: ERROR

        Details:
        In a TPBD document attribute value entsoe:TopologicalNode.fromEndIsoCode
        must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.

        Justification:
        See IEC TS 61970-600-1:2017 B.5.

        Message:
        Country code used that is not in the reference data.

        Usage: #IGMRuleSet


Rule: CNToEndIsoCode  Level: 3  Severity: ERROR

        Details:
        In an EQBD document attribute value entsoe:ConnectivityNode.toEndIsoCode
        must be from the country code list – field 'TsoCodeList' in the QoCDC Reference
Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.

        Justification:
        See IEC TS 61970-600-1:2017 B.6.

        Message:
        Country code used that is not in the reference data.
```

Usage: #IGMRuleSet

Rule: TNToEndIsoCode Level: 3 Severity: ERROR

Details:
In a TPBD document attribute value entsoe:TopologicalNode.toEndIsoCode must be from the country code list – field 'TsoCodeList' in the QoCDC Reference Data document which is a subset of https://www.iso.org/iso-3166-country-codes.html.

Justification:
See IEC TS 61970-600-1:2017 B.6.

Message:
Country code used that is not in the reference data.

Usage: #IGMRuleSet

Rule: CNFromEndNameLength Level: 3 Severity: ERROR

Details:
In every EQBD model instance, the length of all instances of entsoe:ConnectivityNode.fromEndName shall not exceed IO_NAME_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.7.

Message:
Length of name attribute exceeds IO_NAME_LENGTH characters.

Usage: #IGMRuleSet

Rule: TNFromEndNameLength Level: 3 Severity: ERROR

Details:
In every TPBD model instance, the length of all instances of entsoe:TopologicalNode.fromEndName shall not exceed IO_NAME_LENGTH characters.

Justification:
See IEC TS 61970-600-1:2017 B.7.

Message:
Length of name attribute exceeds IO_NAME_LENGTH characters.

Usage: #IGMRuleSet

Rule: CNToEndNameLength Level: 3 Severity: ERROR

Details:
In every EQBD model instance, the length of all instances of entsoe:ConnectivityNode.toEndName shall not exceed IO_NAME_LENGTH characters.

```
1453          Justification:
1454          See IEC TS 61970-600-1:2017 B.8.
1455
1456          Message:
1457          Length of name attribute exceeds IO_NAME_LENGTH characters.
1458
1459          Usage: #IGMRuleSet
1460
1461    Rule: TNToEndNameLength  Level: 3  Severity: ERROR
1462
1463          Details:
1464          In every TPBD model instance, the length of all instances of
1465          entsoe:TopologicalNode.toEndName shall not exceed IO_NAME_LENGTH
1466          characters.
1467
1468          Justification:
1469          See IEC TS 61970-600-1:2017 B.8.
1470
1471          Message:
1472          Length of name attribute exceeds IO_NAME_LENGTH characters.
1473
1474          Usage: #IGMRuleSet
1475
1476    Rule: CNFromEndNameTsoLength  Level: 3  Severity: ERROR
1477
1478          Details:
1479          In every EQBD model instance, the length of all instances of
1480          entsoe:ConnectivityNode.fromEndNameTso shall not exceed IO_NAME_LENGTH
1481          characters.
1482
1483          Justification:
1484          See IEC TS 61970-600-1:2017 B.9.
1485
1486          Message:
1487          Length of name attribute exceeds IO_NAME_LENGTH characters.
1488
1489          Usage: #IGMRuleSet
1490
1491    Rule: TNFromEndNameTsoLength  Level: 3  Severity: ERROR
1492
1493          Details:
1494          In every TPBD model instance, the length of all instances of
1495          entsoe:TopologicalNode.fromEndNameTso shall not exceed IO_NAME_LENGTH
1496          characters.
1497
1498          Justification:
1499          See IEC TS 61970-600-1:2017 B.9.
1500
1501          Message:
1502          Length of name attribute exceeds IO_NAME_LENGTH characters.
1503
1504          Usage: #IGMRuleSet
1505
1506    Rule: CNToEndNameTsoLength  Level: 3  Severity: ERROR
1507
1508          Details:
```

```
1509        In every EQBD model instance, the length of all instances of
1510        entsoe:ConnectivityNode.toEndNameTso shall not exceed IO_NAME_LENGTH
1511        characters.
1512
1513        Justification:
1514        See IEC TS 61970-600-1:2017 B.10.
1515
1516        Message:
1517        Length of name attribute exceeds IO_NAME_LENGTH characters.
1518
1519        Usage: #IGMRuleSet
1520
1521
1522    Rule: TNToEndNameTsoLength  Level: 3  Severity: ERROR
1523
1524        Details:
1525        In every TPBD model instance, the length of all instances of
1526        entsoe:TopologicalNode.toEndNameTso shall not exceed IO_NAME_LENGTH
1527        characters.
1528
1529        Justification:
1530        See IEC TS 61970-600-1:2017 B.10.
1531
1532        Message:
1533        Length of name attribute exceeds IO_NAME_LENGTH characters.
1534
1535        Usage: #IGMRuleSet
1536
1537    Rule: ShuntCompensatorSensitivity  Level: 3  Severity: ERROR
1538
1539        Details:
1540        The following attribute value shall be greater than zero
1541        - cim:ShuntCompensator.voltageSensitivity
1542
1543        Justification:
1544        Decision from 2018-11-09 CGM_BP/EMF meeting.
1545        It was concluded that a negative value is not physically possible.
1546
1547        Message:
1548        VoltageSensitivity attribute value shall be greater than zero.
1549
1550        Usage: #IGMRuleSet
1551
1552    Rule: NumberOfSubstations  Level: 3  Severity: WARNING
1553
1554        Details:
1555        The following number of cim:Substations in an IGM are considered suspicious
1556        - a single cim:Substation which is the min limit.
1557        - one cim:Substation per cim:VoltageLevel which is the max limit.
1558        The upper limit for the number of cim:Substations equals the number of
1559        cim:VoltageLevels.
1560
1561        Justification:
1562        The number of cim:Substations should reflect the design of the power system.
1563
1564        Message:
```

```
1565          The number of cim:Substations does not reflect the design of the power system.
1566
1567          Usage: #IGMRuleSet
1568
1569    Rule: GenerationContainment  Level: 3  Severity: ERROR
1570
1571          Details:
1572          For every instance of cim:HydroPump and cim:GeneratingUnit (and subclasses
1573          thereof), the cim:Equipment.EquipmentContainer referred to,
1574          must be of type cim:Substation. Missing containment is not allowed.
1575
1576          Justification:
1577          See Figure 15 (Core notes) of IEC TS 61970-600-2 section 6.7.11.
1578
1579          Message:
1580          cim:HydroPump and cim:GeneratingUnit must be contained in a cim:Substation.
1581
1582          Usage: #IGMRuleSet
1583
1584    Rule: PTContainment  Level: 3  Severity: ERROR
1585
1586          Details:
1587          For every instance of cim:PowerTransformer, the
1588          cim:Equipment.EquipmentContainer referred to, must be of type
1589          cim:Substation or of type cim:DCConverterUnit. Missing containment is not allowed.
1590
1591          Justification:
1592          See Figure 15 (Core notes) and Figure 5 (diagram DCContainment)
1593          of IEC TS 61970-600-2 sections 6.7.11 and 6.3.9.
1594
1595          Message:
1596          A cim:PowerTransformer must be contained in a cim:Substation
1597          or a cim:DCConverterUnit.
1598
1599          Usage: #IGMRuleSet
1600
1601    Rule: SwitchContainment  Level: 3  Severity: ERROR
1602
1603          Details:
1604          For every instance of Switch (and subclasses thereof), the
1605          cim:Equipment.EquipmentContainer referred to, must be of type
1606          VoltageLevel, of type Bay or of type DCConverterUnit.
1607          Missing containment is not allowed.
1608
1609          Justification:
1610          See Figure 15 (Core notes) and Figure 5 (diagram DCContainment)
1611          of IEC TS 61970-600-2 sections 6.7.11 and 6.3.9.
1612
1613          Message:
1614          Switches must be contained in a VoltageLevel, a Bay or a DCConverterUnit.
1615
1616          Usage: #IGMRuleSet
1617
1618    Rule: SCContainment  Level: 3  Severity: ERROR
1619
1620          Details:
```

```
1621          For every instance of cim:SeriesCompensator, the
1622          cim:Equipment.EquipmentContainer referred to, if provided, must be of
1623          type cim:Line, of type cim:VoltageLevel or of type cim:DCConverterUnit.
1624
1625          Justification:
1626          See Figure 15 (diagram Core notes) in section 6.7.1 of IEC TS 61970-600-2,
1627          Figure 5 (diagram DCContainment) in section 6.3.1 of IEC TS 61970-600-2
1628          and section 6.9.16 of IEC TS 61970-600-2.
1629
1630          Message:
1631          A cim:SeriesCompensator can only be contained in a cim:Line, a cim:VoltageLevel
1632          or a cim:DCConverterUnit.
1633
1634          Usage: #IGMRuleSet
1635
1636    Rule: InjectionContainment  Level: 3  Severity: ERROR
1637
1638          Details:
1639          For every instance of cim:EnergyConsumer subclasses, cim:RotatingMachine
1640          subclasses, cim:ShuntCompensator subclasses, cim:EnergySource,
1641          cim:EquivalentShunt, cim:ExternalNetworkInjection and cim:StaticVarCompensator,
1642          the cim:Equipment.EquipmentContainer referred to, must be of type
1643          cim:VoltageLevel. Missing containment is not allowed.
1644
1645          Justification:
1646          See 6.10.10, 6.7.6 of IEC TS 61970-600-2.
1647
1648          Message:
1649          Injections must be contained in a cim:VoltageLevel.
1650
1651          Usage: #IGMRuleSet
1652
1653    Rule: BusbarSectionContainment  Level: 3  Severity: ERROR
1654
1655          Details:
1656          For every instance of cim:BusbarSection, the cim:Equipment.EquipmentContainer
1657          referred to, must be of type cim:VoltageLevel. Missing containment is not allowed.
1658
1659          Justification:
1660          See Figure 15 (diagram Core notes) of IEC TS 61970-600-2 section 6.10.5.
1661
1662          Message:
1663          A cim:BusbarSection must be contained in a cim:VoltageLevel.
1664
1665          Usage: #IGMRuleSet
1666
1667    Rule: EFCContainment  Level: 3  Severity: ERROR
1668
1669          Details:
1670          For every instance of cim:EarthFaultCompensator, its subclasses and cim:Ground,
1671          the cim:Equipment.EquipmentContainer referred to, must be of type
1672          cim:VoltageLevel. Missing containment is not allowed.
1673
1674          Justification:
1675          See Figure 15 (diagram Core notes) of IEC TS 61970-600-2 section 6.7.6.
1676
```

1677 Message:
1678 A subclass of cim:EarthFaultCompensator or cim:Ground must be contained in a
1679 cim:VoltageLevel.
1680
1681 Usage: #IGMRuleSet
1682
1683 Rule: JunctionContainment Level: 3 Severity: ERROR
1684
1685 Details:
1686 For every instance of cim:Junction (Equipment Boundary file), the
1687 cim:Equipment.EquipmentContainer referred to, must be of type cim:Line.
1688 Missing containment is not allowed.
1689
1690 Justification:
1691 See section 4.4.5 of IEC TS 61970-600-2.
1692
1693 Message:
1694 A cim:Junction must be contained in a cim:Line.
1695
1696 Usage: #IGMRuleSet
1697
1698 Rule: ACDCConvContainment Level: 3 Severity: ERROR
1699
1700 Details:
1701 For every instance of cim:CsConverter and cim:VsConverter, the
1702 cim:Equipment.EquipmentContainer referred to, must be of type
1703 cim:DCConverterUnit. Missing containment is not allowed.
1704
1705 Justification:
1706 See section 6.3.2 of IEC TS 61970-600-2.
1707
1708 Message:
1709 A cim:ACDCConverter must be contained in a cim:DCConverterUnit.
1710
1711 Usage: #IGMRuleSet
1712
1713 Rule: DCEQContainment Level: 3 Severity: ERROR
1714
1715 Details:
1716 For every instance of cim:DCSeriesDevice, cim:DCShunt, cim:DCBusbar, cim:DCGround,
1717 cim:DCChopper, cim:DCSwitch, cim:DCBreaker and cim:DCDisconnector, the
1718 cim:Equipment.EquipmentContainer referred to, must be of type
1719 cim:DCConverterUnit. Missing containment is not allowed.
1720
1721 Justification:
1722 See section 6.3.2 of IEC TS 61970-600-2.
1723
1724 Message:
1725 All DC equipment, except cim:DCLineSegment must be contained in a
1726 cim:DCConverterUnit.
1727
1728 Usage: #IGMRuleSet
1729
1730 Rule: CNContainment Level: 3 Severity: ERROR
1731
1732 Details:

```
        For cim:ConnectivityNodes according to EQ, the
        cim:ConnectivityNode.ConnectivityNodeContainer referred to, must be
        of type cim:VoltageLevel, cim:Bay or cim:Line.
        For cim:ConnectivityNodes according to EQBD, the
        cim:ConnectivityNode.ConnectivityNodeContainer referred to,
        must be of type cim:Line. Missing containment is not allowed.

        Justification:
        See Figure 1 (diagram EquipmentBoundaryProfile), figure 15 (diagram
        Core Notes), section 6.7.7 of IEC TS 61970-600-2.

        Message:
        cim:ConnectivityNode must be contained in a cim:VoltageLevel, cim:Bay
        or cim:Line for EQ models and in a cim:Line for Boundary points.

        Usage: #IGMRuleSet

Rule: CNTerminals  Level: 3  Severity: WARNING

        Details:
        cim:ConnectivityNodes that:
        - are isolated and do not have any Terminals connecting to equipment.
        - have one Terminal that connect to a dead equipment end.

        Justification:
        Isolated or dead end cim:ConnectivityNodes may indicate a connectivity issue.

        Message:
        Isolated or dead end ConnectivityNodes may indicate a connectivity issue.

        Usage: #IGMRuleSet

Rule: GeneratingUnitNominalP  Level: 3  Severity: WARNING

        Details:
        According to CGMES the value of cim:GeneratingUnit.nominalP should be positive
        and less or equal to cim:RotatingMachine.ratedS.

        Justification:
        See section 6.6.5 of IEC TS 61970-600-2.

        Message:
        cim:GeneratingUnit.nominalP outside allowed range.

        Usage: #IGMRuleSet

Rule: CEBaseVoltage  Level: 3  Severity: ERROR

        Details:
        All  cim:ConductingEquipment  except  cim:ACLineSegment,  cim:SeriesCompensator,
cim:EquivalentBranch
        and cim:PowerTransformer, must either have an association with cim:BaseVoltage
        or be located within a cim:VoltageLevel or cim:Bay. The exception is because rule
BranchBaseVoltage validates similar conditions.
```

If both cim:ConductingEquipment.BaseVoltage and containment in a cim:VoltageLevel or cim:Bay are provided, the association ends cim:ConductingEquipment.BaseVoltage and cim:VoltageLevel.BaseVoltage shall refer to the same cim:BaseVoltage.

Justification:
See section 6.7.6 and 6.10.2 of IEC TS 61970-600-2.

Message:
cim:ConductingEquipment that does not have cim:BaseVoltage or refers to different cim:BaseVoltage via different associations.

Usage: #IGMRuleSet

Rule: NominalVoltage Level: 3 Severity: ERROR

Details:
For every instance of cim:BaseVoltage, the cim:BaseVoltage.nominalVoltage value must be greater than zero.

Justification:
See section 6.7.3 of IEC TS 61970-600-2.

Message:
Nominal voltage must be greater than zero.

Usage: #IGMRuleSet

Rule: InstancesOfGeneralClass Level: 3 Severity: ERROR

Details:
The most specific and detailed class shall in general be instantiated.
Hence more general classes shall not be instantiated. The following classes are specifically noted as not allowed to instantiate
- cim:EnergyConsumer

Justification:
The level of detail described by the more specific class are needed in studies.
The approved methodologies:
CGMM-v1-plus Article 9, Load, 4(c) (as well CGMM-v2-plus.and CGMM-v3 referencing to CGMM-v1-plus) and GLDPM-v1: Article 2, Definitions and interpretation, point 3 and 7, Article 11, 4(9) (as well GLDPM-v2 referencing to GLDPM-v1) foresee the provision of conforming and non-conforming load flag as well as approved EMF Requirements, which implies the use specific classes of EnergyConsumer.
IEC 61970-600-1:2017 Common Grid Model Exchange Specification, 5.1 General constraints, GENC11: Instance data to be exchanged must make use of the most detailed class possible within a profile, i.e. using sub-typed classes rather than general classes, e.g. NuclearGeneratingUnit instead GeneratingUnit.
Note that this rule is not applied for GeneratingUnit.

Message:
Instances of type cim:EnergyConsumer are not allowed, the usage of its subclasses is mandatory.

Usage: #IGMRuleSet

```
Rule: TerminalCount1  Level: 3  Severity: ERROR

      Details:
      Every instance of cim:RegulatingCondEq and its subclasses, cim:EnergyConsumer
      and its subclasses, cim:EquivalentInjection, cim:EquivalentShunt, subclasses of
      cim:Connector, cim:EnergySource, cim:Ground,
      cim:DCBusbar, cim:DCShunt, cim:DCGround
      shall only be referenced via a single cim:Terminal instance.

      Justification:
      cim:ConductingEqupment with a single electrical connection point shall only have
      one cim:Terminal.

      Message:
      Single terminal devices must not be referenced by multiple terminals.

      Usage: #IGMRuleSet

Rule: TerminalCount2  Level: 3  Severity: ERROR

      Details:
      Every instance of cim:Conductor and its subclasses, cim:Switch and its subclasses,
      cim:SeriesCompensator, cim:EquivalentBranch,
      cim:DCLineSegment,  cim:DCSeriesDevice,  cim:DCChopper  and  subclasses  of
cim:DCSwitch,
      shall only be referenced via exactly two cim:Terminal instances.

      Justification:
      cim:ConductingEqupment with two electrical connection point shall have
      two cim:Terminals.

      Message:
      Two terminal devices must be referenced by exactly two terminals.

      Usage: #IGMRuleSet

Rule: TerminalSeqNum  Level: 3  Severity: ERROR

      Details:
      Every instance of cim:Terminal must have a cim:Terminal.sequenceNumber
      if it belongs to an cim:EquivalentBranch or an cim:ACLineSegment
      with cim:MutualCoupling.

      Justification:
      See section 6.7.21 and 6.10.31 of IEC TS 61970-600-2.

      Message:
      cim:Terminals must have a sequence number if they belong to an cim:EquivalentBranch
      or a cim:ACLineSegment with cim:MutualCoupling.

      Usage: #IGMRuleSet

Rule: TerminalSeqNumOrder  Level: 3  Severity: ERROR

      Details:
```

In cases where cim:Terminal.sequenceNumber is provided for an instance of cim:ConductingEquipment or cim:DCConductingEquipment, at least one sequenceNumber shall equal to 1. The cim:Terminal.sequenceNumber of other terminals of same cim:ConductingEquipment or cim:DCConductingEquipment shall follow increasing order.

Justification:
See section 6.7.2 of IEC TS 61970-600-2.

Message:
Invalid sequenceNumber for cim:Terminal.

Usage: #IGMRuleSet

Rule: PTTerminalConsistency Level: 3 Severity: ERROR

Details:
For every instance of cim:PowerTransformerEnd, the cim:Terminal referenced by the cim:TransformerEnd.Terminal association must be associated with the cim:PowerTransformer instance, referenced via the cim:PowerTransformerEnd.PowerTransformer association.

Justification:
See section 6.9.31 of IEC TS 61970-600-2.

Message:
Terminals for PowerTransformers must be defined unambiguously.

Usage: #IGMRuleSet

Rule: MCFirstSecond Level: 3 Severity: ERROR

Details:
The following shall conform for every instance of cim:MutualCoupling:

1) Association end cim:MutualCoupling.First_Terminal shall refer to a cim:Terminal of an cim:ACLineSegment.
2) Association end cim:MutualCoupling.Second_Terminal shall refer to a cim:Terminal of an cim:ACLineSegment.
3) Association ends cim:MutualCoupling.First_Terminal and cim:MutualCoupling.Second_Terminal shall refer to cim:Terminal-s of different cim:ACLineSegment-s.

Justification:
See section 6.9.19 of IEC TS 61970-600-2.

Message:
One of the following occurs: 1) cim:MutualCoupling.First_Terminal does not refer to a cim:Terminal of a cim:ACLineSegment, 2) cim:MutualCoupling.Second_Terminal does not refer to a cim:Terminal of a cim:ACLineSegment, 3) cim:MutualCoupling.First_Terminal and cim:MutualCoupling.Second_Terminal do not refer to cim:Terminal-s of different cim:ACLineSegment-s.

Usage: #IGMRuleSet

Rule: LRCExponentModel Level: 3 Severity: ERROR

Details:
For every instance of cim:LoadResponseCharacteristic where
cim:LoadResponseCharacteristic.exponentModel is true,
cim:LoadResponseCharacteristic.pVoltageExponent and
cim:LoadResponseCharacteristic.qVoltageExponent must be provided and
be greater or equal than zero and less or equal to two.

Note: The attributes pFrequencyExponent and qFrequencyExponent are not used. The attributes that are required for coefficient load model covered by rule LCRCoefficientModel are ignored and not validated when cim:LoadResponseCharacteristic.exponentModel equals true.

Justification:
See section 6.10.9 of IEC TS 61970-600-2.

Message:
Exponent of per unit voltage effecting real and reactive power must be
specified if cim:LoadResponseCharacteristic.exponentModel is true.

Usage: #IGMRuleSet

Rule: LCRCoefficientModel Level: 3 Severity: ERROR

Details:
For every instance of cim:LoadResponseCharacteristic where
cim:LoadResponseCharacteristic.exponentModel is false,
cim:LoadResponseCharacteristic.pConstantImpedance and
cim:LoadResponseCharacteristic.pConstantCurrent and
cim:LoadResponseCharacteristic.pConstantPower and
cim:LoadResponseCharacteristic.qConstantImpedance and
cim:LoadResponseCharacteristic.qConstantCurrent and
cim:LoadResponseCharacteristic.qConstantPower must be provided.

Note: The attributes that are required for exponential load model covered by rule LRCExponentModel are ignored and not validated when cim:LoadResponseCharacteristic.exponentModel equals false.

Justification:
See section 6.10.9 of IEC TS 61970-600-2.

Message:
Coefficients for ZIP load model must be specified if cim:LoadResponseCharacteristic.exponentModel is false.

Usage: #IGMRuleSet

Rule: LCRCoefficientParameters Level: 3 Severity: ERROR

Details:
For every instance of cim:LoadResponseCharacteristic with
cim:LoadResponseCharacteristic.exponentModel is false, the sum of

cim:LoadResponseCharacteristic.pConstantImpedance and
cim:LoadResponseCharacteristic.pConstantCurrent and
cim:LoadResponseCharacteristic.pConstantPower values must be 1 and
the sum of cim:LoadResponseCharacteristic.qConstantImpedance and
cim:LoadResponseCharacteristic.qConstantCurrent and
cim:LoadResponseCharacteristic.qConstantPower values must be 1.

Justification:
See section 6.10.9 of IEC TS 61970-600-2.

Message:
Invalid coefficient parameters for cim:LoadResponseCharacteristic.

Usage: #IGMRuleSet

Rule: MeasTerminal Level: 3 Severity: ERROR

Details:
The association end cim:Measurement.Terminal shall reference a cim:Terminal of the cim:Equipment referenced by cim:Measurement.PowerSystemResource except in cases where cim:Measurement.measurementType is either cim:TapPosition or cim:SwitchPosition in which the association is not exchanged.

Justification:
See section 6.5.18 of IEC TS 61970-600-2.

Message:
cim:Measurement.Terminal does not refer to a cim:Terminal of a cim:Equipment referenced by cim:Measurement.PowerSystemResource.

Usage: #IGMRuleSet

Rule: MeasType Level: 3 Severity: ERROR

Details:
For every instance of cim:Measurement, the value of
cim:Measurement.measurementType is limited to 'ThreePhasePower',
'ThreePhaseActivePower', 'ThreePhaseReactivePower', 'LineCurrent',
'PhaseVoltage', 'LineToLineVoltage', 'Angle', 'TapPosition',
'SwitchPosition'.

Justification:
See section 6.5.18 of IEC TS 61970-600-2.

Message:
Invalid measurement type.

Usage: #IGMRuleSet

Rule: MeasUnit Level: 3 Severity: ERROR

Details:
For every instance of cim:Measurement, the value of
cim:Measurement.unitSymbol is restricted to 'cim:UnitSymbol.V',
'cim:UnitSymbol.A', 'cim:UnitSymbol.W', 'cim:UnitSymbol.VA',

'cim:UnitSymbol.VAr', 'cim:UnitSymbol.deg', 'cim:UnitSymbol.Hz',
'cim:UnitSymbol.none'.

Justification:
See section 6.5.18 of IEC TS 61970-600-2.

Message:
Invalid measurement unit symbol.

Usage: #IGMRuleSet

Rule: CATieFlow Level: 3 Severity: ERROR

Details:
For every instance of cim:ControlArea for which the value of
cim:ControlArea.type is cim:ControlAreaTypeKind.Interchange,
cim:TieFlow instances must be provided.

Justification:
This is necessary to compute interchange.

Message:
cim:TieFlows must be defined for cim:ControlArea, no cim:TieFlows found.

Usage: #IGMRuleSet

Rule: TargetDB Level: 3 Severity: ERROR

Details:
For every instance of cim:RegulatingControl (SSH) for which the value of
cim:RegulatingControl.discrete is true and cim:RegulatingControl.enabled
is true, cim:RegulatingControl.targetDeadband must be provided and must be greater
than 0.

Justification:
If cim:RegulatingControl.discrete is set to true and no deadband
is provided the power flow algorithm may not reach a solution but may continue
to try find one which results in hunting.

Message:
Target deadband is either not provided if the regulating control is discrete and
active or it is not greater than zero.

Usage: #IGMRuleSet

Rule: OperationalLimitValue Level: 3 Severity: ERROR

Details:
For every instance of cim:VoltageLimit, the value of cim:VoltageLimit.value
must be > 0. For every instance of cim:CurrentLimit, the value
of cim:CurrentLimit.value must be > 0. For every instance of
cim:ActivePowerLimit, the value of cim:ActivePowerLimit.value must be > 0.
For every instance of cim:ApparentPowerLimit, the value of

```
2122        cim:ApparentPowerLimit.value must be > 0.
2123
2124        Justification:
2125        See section 6.8.5 of IEC TS 61970-600-2.
2126
2127        Message:
2128        OperationalLimit values must be positive.
2129
2130        Usage: #IGMRuleSet
2131
2132  Rule: AcceptableDuration  Level: 3  Severity: ERROR
2133
2134        Details:
2135        The usage of the attribute cim:OperationalLimitType.acceptableDuration
2136        depends on the value of the entsoe:OperationalLimitType.limitType attribute as
2137        follows:
2138        - patl: acceptableDuration is not used;
2139        - patlt: usage of acceptableDuration is restricted, i.e. it is not used as another
2140  way to express the severity of the limit;
2141        - tatl: acceptableDuration is used to define several TATL limit types
2142        - tc: acceptableDuration is not used as an immediate tripping is expected
2143        - tct: acceptableDuration is used as the limit is less than the tc limit and
2144           describe how long the violation may sustain before tripping.
2145        If acceptableDuration is not used the attribute can be completely omitted
2146        or if included the acceptableDuration value shall be ignored.
2147
2148        Justification:
2149        See section 6.8.9.1 and 6.8.7 of IEC TS 61970-600-2.
2150
2151        Message:
2152        cim:OperationalLimitType.acceptableDuration is not provided for TATL and TCT limit
2153  types.
2154
2155        Usage: #IGMRuleSet
2156
2157  Rule: OperationalLimitSetAtTerminal  Level: 3  Severity: WARNING
2158
2159        Details:
2160        The association end cim:OperationalLimitSet.Terminal is required.
2161        Note the association end cim:OperationalLimitSet.Equipment is neither checked nor
2162        reported in this rule.
2163
2164        Justification:
2165        The limits in question are related to power flow, hence they are
2166        linked to the cim:Terminal.
2167        Less options also simplifies data exchange.
2168
2169        Message:
2170        The OperationalLimitSet is not linked to a Terminal.
2171
2172        Usage: #IGMRuleSet
2173
2174  Rule: PATL1  Level: 3  Severity: ERROR
2175
2176        Details:
2177        Every instance of cim:ACLineSegment and cim:SeriesCompensator,
```

```
2178        that is not aggregated, shall have at least one
2179        cim:OperationalLimitSet linked to one of its cim:Terminals.
2180        A cim:OperationalLimitSet shall have at least one
2181        cim:OperationalLimit of type entsoe:LimitTypeKind.patl.
2182        Equipment is aggregated when cim:Equipment.aggregate is present
2183        and set to 'true'.
2184
2185        Justification:
2186        See section 6.8.7 of IEC TS 61970-600-2.
2187
2188        Message:
2189        PATL missing for cim:ACLineSegment or cim:SeriesCompensator.
2190
2191        Usage: #IGMRuleSet
2192
2193  Rule: PATL2  Level: 3  Severity: ERROR
2194
2195        Details:
2196        Every instance of cim:PowerTransformer, that is not aggregated
2197  (cim:Equipment.aggregate equals to false or it is missing), shall have at least one
2198  cim:OperationalLimitSet with at least one cim:OperationalLimit of type
2199  entsoe:LimitTypeKind.patl linked to one of cim:Terminal-s of the cim:PowerTransformer.
2200
2201        Justification:
2202        See section 6.8.7 of IEC TS 61970-600-2.
2203
2204        Message:
2205        A non-aggregated cim:PowerTrainsformer which has not a cim:OperationalLimitSet with
2206  at least one cim:OperationalLimit of type entsoe:LimitTypeKind.patl associated to any of
2207  its cim:Terminal-s.
2208
2209        Usage: #IGMRuleSet
2210
2211
2212  Rule: PATL3  Level: 3  Severity: ERROR
2213
2214        Details:
2215        There shall be only one PATL limitType per cim:OperationalLimitSet and type
2216        - cim:ActivePowerLimit
2217        - cim:CurrentLimit or cim:ApparentPowerLimit
2218        This means that an cim:OperationalLimitSet may have two PATL values, one for
2219        cim:CurrentLimit or cim:ApparentPowerLimit and one for cim:ActivePowerLimit.
2220
2221        Justification:
2222        See section 6.8.9.1 of IEC TS 61970-600-2.
2223
2224        Message:
2225        Redundant PATL not allowed for OperationalLimitSet.
2226
2227        Usage: #IGMRuleSet
2228
2229  Rule: PATL4  Level: 3  Severity: WARNING
2230
2231        Details:
2232        For an instance of cim:ACLineSegment or cim:SeriesCompensator the limit values
2233        of the same cim:OperationalLimitType.limitType shall not differ more than
```

```
2234          PATL_LIMIT_VALUE_DIFF between the two sides, e.g. a cim:CurrentLimit
2235          of type PATL.
2236
2237          Justification:
2238          Based on engineering practice.
2239
2240          Message:
2241          Differing limit values on two sides of the equipment above PATL_LIMIT_VALUE_DIFF.
2242
2243          Usage: #IGMRuleSet
2244
2245    Rule: PATL5  Level: 3  Severity: WARNING
2246
2247          Details:
2248          PATL type on voltage limits shall be ignored.
2249
2250          Justification:
2251          See section 6.8.9.1 of IEC TS 61970-600-2:2017.
2252
2253          Message:
2254          PATL voltage limit is ignored.
2255
2256          Usage: #IGMRuleSet
2257
2258    Rule: CNRequiredInEQOperations  Level: 3  Severity: ERROR
2259
2260          Details:
2261          The association end cim:Terminal.ConnectivityNode is required in cases where
2262          EQ Operation profile is specified in the header.
2263          The different kinds of models are described in IEC TS 61970-600-1:2017 PROF4.
2264
2265          Justification:
2266          See section 6.7.7 and rules PROF4 and PROF5 of IEC TS 61970-600-1:2017.
2267
2268          Message:
2269          The association end cim:Terminal.ConnectivityNode is not provided for a  model that
2270    contains EQ Operation profile.
2271
2272          Usage: #IGMRuleSet
2273
2274
2275    Rule: EnergySourceVoltage  Level: 3  Severity: ERROR
2276
2277          Details:
2278          For cim:EnergySource the attributes voltageMagnitude and voltageAngle
2279          are optional to include in EQ. The attributes are intended for the
2280          case when a strong network is providing power to a weak
2281          distribution network. Hence it is wrong to use these attributes
2282          in transmission studies and they shall not at all be used.
2283
2284          Justification:
2285          The use case for these attributes is not appropriate for transmission.
2286          See IEC TS 61970-600-1:2017 section E.19.
2287
2288          Message:
2289          The use case for cim:EnergySource attributes voltageMagnitude
```

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2290          and voltageAngle is not allowed for transmission.
2291
2292          Usage: #IGMRuleSet
2293
2294    Rule: ControlModeCompatibility  Level: 3  Severity: ERROR
2295
2296          Details:
2297          The cim:TapChangerControl or cim:RegulatingControl can only do control compatible
2298    with its type,
2299          - A phase shift tap changer can only do the cim:RegulatingControl.mode
2300              - active power control
2301          - A ratio tap changer can only do the cim:RegulatingControl.mode-s
2302              - voltage
2303              - reactivePower
2304              - powerFactor
2305          - A cim:SynchronousMachine or cim:ShuntCompensator instance can only
2306            do the cim:RegulatingControl.mode-s
2307              - voltage
2308              - reactivePower
2309              - powerFactor
2310          - A cim:StativeVarCompensator can only do the cim:RegulatingControl.mode-s
2311              - voltage
2312              - reactivePower
2313          - A cim:BusbarSection instance can only be controlled by a cim:RegulatingControl
2314          in mode (cim:RegulatingControl.mode):
2315              - voltage
2316
2317          The following cim:RegulatingControl.modes are not at all allowed
2318              - currentFlow
2319              - admittance
2320              - timeScheduled
2321              - temperature
2322
2323
2324          Justification:
2325          Only meaningful combinations of data are allowed.
2326
2327          Message:
2328          cim:TapChangerControl or cim:RegulatingControl with invalid
2329          cim:RegulatingControl.mode.
2330
2331          Usage: #IGMRuleSet
2332
2333    Rule: ACLineSegmentR  Level: 3  Severity: ERROR
2334
2335          Details:
2336          For every instance of cim:ACLineSegment the value of
2337          cim:ACLineSegment.r must be greater than or equal to zero.
2338
2339          Justification:
2340          Negative resistance means negative losses.
2341          This is not allowed for real equipment.
2342
2343          Message:
2344          Negative resistance not allowed for cim:ACLineSegment.
2345
```

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2346          Usage: #IGMRuleSet
2347
2348
2349    Rule: ACLineSegmentX  Level: 3  Severity: WARNING
2350
2351          Details:
2352          For every instance of cim:ACLineSegment the value of
2353          cim:ACLineSegment.x should be greater than or equal to EQ_BRANCH_X_LIMIT Ohm.
2354
2355          Justification:
2356          Too small impedances cause numerical instability when
2357          solving the power flow.
2358
2359          Message:
2360          Reactance value should be greater than or equal to EQ_BRANCH_X_LIMIT.
2361
2362          Usage: #IGMRuleSet
2363
2364    Rule: SeriesCompensatorX  Level: 3  Severity: WARNING
2365
2366          Details:
2367          For every instance of cim:SeriesCompensator the value of
2368          abs(cim:SeriesCompensator.x) should be greater than or equal to
2369          EQ_BRANCH_X_LIMIT Ohm.
2370
2371          Justification:
2372          Too small impedances cause numerical instability when
2373          solving the power flow.
2374
2375          Message:
2376          Reactance value should be greater than or equal to EQ_BRANCH_X_LIMIT.
2377
2378          Usage: #IGMRuleSet
2379
2380
2381    Rule: EquivalentBranchX  Level: 3  Severity: WARNING
2382
2383          Details:
2384          For every instance of EquivalentBranch (EB) the total impedance should be greater
2385          than or equal to EQ_BRANCH_X_LIMIT Ohm. The total impedance is computed by sqrt(EB.x
2386    * EB.x + EB.x21 * EB.x21). In cases where EB.x21 is not provided, it is equal to zero in
2387    the equation for calculation of the total impedance.
2388
2389          Justification:
2390          Too small impedances cause numerical instability when
2391          solving the power flow.
2392
2393          Message:
2394          Total impedance should be greater than or equal to EQ_BRANCH_X_LIMIT Ohm.
2395
2396          Usage: #IGMRuleSet
2397
2398    Rule: DCLineSegmentR  Level: 3  Severity: ERROR
2399
2400          Details:
2401          For every instance of cim:DCLineSegment the value of
```

2402 cim:DCLineSegment.resistance and the value of the associated
2403 cim:PerLengthDCLineParameter.resistance must be greater than zero.
2404
2405 Justification:
2406 Negative resistance means negative losses.
2407 This is not allowed for real equipment.
2408
2409 Message:
2410 Negative resistance not allowed for cim:DCLineSegment.
2411
2412 Usage: #IGMRuleSet
2413
2414 Rule: PowerTransformerEndR Level: 3 Severity: WARNING
2415
2416 Details:
2417 cim:PowerTransformerEnd.r shall conform to the following rules:
2418 - Be equal to 0 Ohm for the 2nd winding (the winding with
2419 cim:TransformerEnd.endNumber = 2, i.e. lower voltage end) of a two-winding
2420 transformer;
2421 - Be greater than or equal to EQ_BRANCH_X_LIMIT Ohm for the 1st winding (the
2422 winding with cim:TransformerEnd.endNumber = 1, i.e. highest voltage end) of a
2423 two-winding transformer;
2424 - Be greater than or equal to EQ_BRANCH_X_LIMIT Ohm for all windings of a three-
2425 winding transformer.
2426
2427 Justification:
2428 Negative resistance means negative losses.
2429 This is not allowed for real equipment.
2430
2431 Message:
2432 PowerTransformerEnd.r is either: 1) different than 0 Ohm for 2nd winding of a two-
2433 winding transformer or 2) not greater than or equal to EQ_BRANCH_X_LIMIT Ohm for all
2434 windings of a three-winding transformer or 3) not greater than or equal to
2435 EQ_BRANCH_X_LIMIT Ohm for 1st winding of a two-winding transformer.
2436
2437 Usage: #IGMRuleSet
2438
2439
2440 Rule: PowerTransformerEndRatedU Level: 3 Severity: WARNING
2441
2442 Details:
2443 The cim:PowerTransformerEnd.ratedU attribute must be greater than zero.
2444
2445 Justification:
2446 The cim:PowerTransformerEnd.ratedU attribute is used in pu calculations.
2447
2448 Message:
2449 cim:PowerTransformerEnd.ratedU should be greater than zero.
2450
2451 Usage: #IGMRuleSet
2452
2453 Rule: PowerTransformerEndX Level: 3 Severity: WARNING
2454
2455 Details:
2456 cim:PowerTransformerEnd.x shall conform to the following rules:

- Be greater than or equal to EQ_BRANCH_X_LIMIT Ohm for the 1st winding (the winding with cim:TransformerEnd.endNumber = 1, i.e. highest voltage end) of a two-winding transformer;
- Be equal to 0 Ohm for the 2nd winding (the winding with cim:TransformerEnd.endNumber = 2, i.e. lower voltage end) of a two-winding transformer;
- the abs(cim:PowerTransformerEnd.x) be greater than or equal to EQ_BRANCH_X_LIMIT Ohm for all windings of a three-winding transformer.

Justification:
Transformers with zero series reactance do not exist.
At a two winding transformer the series reactance is specified
at the high voltage side and the low voltage side isn't used.

Message:
One of the following occurs: 1) The value of 1st winding (cim:TransformerEnd.endNumber = 1) is not greater than or equal to EQ_BRANCH_X_LIMIT Ohm for a two-winding transformer. 2) The value of 2nd winding (cim:TransformerEnd.endNumber = 2) is not 0 Ohm. 3) The absolute value is not greater than or equal to EQ_BRANCH_X_LIMIT Ohm for each of the windings of a three-winding transformer.

Usage: #IGMRuleSet

Rule: LinearShuntCompensatorG Level: 3 Severity: ERROR

Details:
For every instance of cim:LinearShuntCompensator the value of
cim:LinearShuntCompensator.gPerSection must be greater than or
equal to zero.

Justification:
The charging conductance represents the losses, which should
be non-negative.

Message:
cim:LinearShuntCompensator gPerSection must be non-negative.

Usage: #IGMRuleSet

Rule: ShuntCompensatorSections Level: 3 Severity: ERROR

Details:
For every instance of cim:ShuntCompensator the value of
cim:ShuntCompensator.normalSections must be greater than or equal to zero
and less or equal to cim:ShuntCompensator.maximumSections.

Justification:
The sections specify the shunt compensator sections in use,
which should be non-negative.

Message:
cim:ShuntCompensator.normalSections outside allowed range.

Usage: #IGMRuleSet

```
Rule: ConverterLosses  Level: 3  Severity: ERROR

      Details:
      For every instance of cim:CsConverter and cim:VsConverter, the value
      of cim:ACDCConverter.idleLoss, cim:ACDCConverter.switchingLoss and
      cim:ACDCConverter.resistiveLoss, if provided, must be greater than
      or equal to zero.

      Justification:
      Losses cannot be negative.

      Message:
      Negative losses are not allowed for Converter, losses must
      be greater than or equal to zero.

      Usage: #IGMRuleSet

Rule: SVCRatings  Level: 3  Severity: WARNING

      Details:
      For every instance of cim:StaticVarCompensator, the value of
      cim:StaticVarCompensator.capacitiveRating must be positive. The
      value of cim:StaticVarCompensator.inductiveRating must be negative.
      Zero values are not allowed.

      Justification:
      See IEC TS 61970-600-2:2017, section 6.9.44.

      Message:
      Capacitive rating should be greater than zero, inductive rating should
      be lower than zero for SVC.

      Usage: #IGMRuleSet

Rule: SVCSlope  Level: 3  Severity: ERROR

      Details:
      The cim:StaticVarCompensator.slope must be positive or zero.

      Justification:
      The reactive power output of the SVC is proportional to the
      difference between the voltage at the regulated bus and the voltage
      setpoint. When the regulated bus voltage is equal to the voltage
      setpoint, the reactive power output is zero.
      cim:RequlatingControl is used as it has capabilities missing from SVC,
      e.g. the controlled point.

      Message:
      cim:StaticVarCompensator.slope must be positive or zero.

      Usage: #IGMRuleSet

Rule: GeneratingUnitMaxPGen  Level: 3  Severity: ERROR

      Details:
```

2569 For every instance of cim:GeneratingUnit, cim:HydroGeneratingUnit,
2570 cim:NuclearGeneratingUnit, cim:SolarGeneratingUnit, cim:ThermalGeneratingUnit and
2571 cim:WindGeneratingUnit, with cim:SynchronousMachine.type equal to generator
2572 (cim:SynchronousMachineKind.generator), the value
2573 of cim:GeneratingUnit.maxOperatingP must be greater than zero.
2574 Note that the limits follow generation sign convention.
2575
2576 Justification:
2577 The name plate ratings are used as a reference.
2578
2579 Message:
2580 Invalid operating limit, cim:GeneratingUnit.maxOperatingP must
2581 be greater than zero.
2582
2583 Usage: #IGMRuleSet
2584
2585 Rule: SynchronousCondenser Level: 3 Severity: ERROR
2586
2587 Details:
2588 A synchronous condenser (cim:SynchronousMachine.type equal to
2589 SynchronousMachineKind.condenser) has no capability for active power output. Therefore,
2590 such cim:SynchronousMachine shall not be associated with a cim:GeneratingUnit.
2591
2592
2593 Justification:
2594 The name plate ratings are used as a reference.
2595 See IEC TS 61970-600-2:2017, section 6.9.47.
2596
2597 Message:
2598 A synchronous condenser is associated with cim:GeneratingUnit.
2599
2600 Usage: #IGMRuleSet
2601
2602 Rule: SMQLimits1 Level: 3 Severity: WARNING
2603
2604 Details:
2605 For a cim:SynchronousMachine, the value of
2606 cim:SynchronousMachine.maxQ should be greater than or equal to the value
2607 of cim:SynchronousMachine.minQ, if provided.
2608 Note that the limits follow generation sign convention.
2609
2610
2611 Justification:
2612 The name plate ratings are used as a reference.
2613
2614 Message:
2615 Invalid operating limits for Synchronous Machine.
2616
2617 Usage: #IGMRuleSet
2618
2619 Rule: SMQLimits2 Level: 3 Severity: ERROR
2620
2621 Details:
2622 For a cim:SynchronousMachine, either
2623 cim:SynchronousMachine.minQ and cim:SynchronousMachine.maxQ must be
2624 provided, or an association to a cim:ReactiveCapabilityCurve must exist. If

```
2625          cim:ReactiveCapabilityCurve exists cim:SynchronousMachine.minQ
2626          and cim:SynchronousMachine.maxQ shall be ignored.
2627
2628          Justification:
2629          See IEC TS 61970-600-2:2017, section 6.9.47.
2630
2631          Message:
2632          Missing operating limits for Synchronous Machine.
2633
2634          Usage: #IGMRuleSet
2635
2636    Rule: RatedS  Level: 3  Severity: ERROR
2637
2638          Details:
2639          cim:RotatingMachine.ratedS is required and shall be greater than zero.
2640          cim:PowerTransfomerEnd.ratedS is required and shall be greater than zero.
2641          Justification:
2642          RatedS is required for data validation.
2643          See IEC TS 61970-600-2:2017, section 6.9.41.
2644
2645          Message:
2646          cim:RotatingMachine.ratedS or cim:PowerTransfomerEnd.ratedS is either not provided
2647    or it is zero.
2648
2649          Usage: #IGMRuleSet
2650
2651    Rule: SMQLimits3  Level: 3  Severity: WARNING
2652
2653          Details:
2654          For every instance of cim:SynchronousMachine with exactly one cim:GeneratingUnit
2655          the following rules applies
2656          - abs(maxP) Less or Equal ratedS
2657          - abs(minP) Less or Equal ratedS
2658          - abs(maxQ) Less or Equal ratedS
2659          - abs(minQ) Less or Equal ratedS
2660          where
2661          - maxP is cim:GeneratingUnit.maxOperatingP
2662          - maxQ is cim:SynchronousMachine.maxQ
2663          - minP is cim:GeneratingUnit.minOperatingP
2664          - minQ is cim:SynchronousMachine.minQ
2665          - ratedS is cim:RotatingMachine.ratedS
2666
2667          Justification:
2668          The limit values should be inside the rated capability.
2669
2670          Message:
2671          Inconsistent cim:SynchronousMachine and cim:GeneratingUnit limits.
2672
2673          Usage: #IGMRuleSet
2674
2675
2676    Rule: SMPLimits Level: 3  Severity: WARNING
2677
2678          Details:
```

```
2679        For a cim:SynchronousMachine associated with a cim:GeneratingUnit or its
2680        subclasses, the active power limits should relate to cim:SynchronousMachine.type
2681        as follows:
2682        - generator or generatorOrCondenser,
2683           cim:GeneratingUnit.minOperatingP greater than or equal to 0,
2684           cim:GeneratingUnit.maxOperatingP greater than 0,
2685         cim:GeneratingUnit.maxOperatingP     greater     than     or     equal     to
2686         cim:GeneratingUnit.minOperatingP.
2687        - motor or motorOrCondenser,
2688           cim:GeneratingUnit.minOperatingP less than 0,
2689           cim:GeneratingUnit.maxOperatingP less than or equal to 0,
2690           cim:GeneratingUnit.maxOperatingP     greater     than     or     equal     to
2691           cim:GeneratingUnit.minOperatingP.
2692        - generatorOrMotor or generatorOrCondenserOrMotor,
2693           cim:GeneratingUnit.minOperatingP less than 0 and
2694           cim:GeneratingUnit.maxOperatingP greater than 0.
2695
2696        Note:
2697           1) As there is no cim:GeneratingUnit associated with cim:SynchronousMachine in
2698              cases of condenser only type, the condenser cannot be included in this rule.
2699           2) Depending on sign conventions of applications applied to motor operating
2700              mode, the meaning operating active power limits defined by
2701              cim:GeneratingUnit.maxOperatingP and cim:GeneratingUnit.minOperatingP maybe
2702              affected. For instance, if maxOperatingP=-5 and minOperatingP=-100 the
2703              instance data will pass the validation in case it is a motor. However, for
2704              an application which has positive limits (e.g. Pmax and Pmin) for motor
2705              mode, the mapping would be Pmax = minOperatingP and Pmin = maxOperatingP.
2706
2707        Justification:
2708        The active power limit values depend on the cim:SynchronousMachine.type
2709        and this dependence need to be described.
2710
2711        Message:
2712        The active power limit values do not match the cim:SynchronousMachine.type.
2713
2714        Usage: #IGMRuleSet
2715
2716   Rule: CurveStyle  Level: 3  Severity: ERROR
2717
2718        Details:
2719        The cim:Curve.curveStyle enumerated value cim:CurveStyle.constantYValue
2720        is not allowed.
2721
2722        Justification:
2723        The cim:CurveStyle.constantYValue gives too inaccurate
2724        compared with cim:CurveStyle.straightLineYValues.
2725
2726        Message:
2727        The cim:CurveStyle.constantYValue enumeration is not allowed.
2728
2729        Usage: #IGMRuleSet
2730
2731   Rule: RCCYValues  Level: 3  Severity: ERROR
2732
2733        Details:
2734        For every instance of cim:CurveData, for which the cim:CurveData.Curve
```

```
2735        refers to a cim:ReactiveCapabilityCurve, the cim:CurveData.y2value
2736        must be greater or equal than cim:CurveData.y1value.
2737        If cim:CurveData.y2value and cim:CurveData.y1value are equal for all
2738        curve points this is considered an error. It is not allowed that
2739        all CurveData.y2value values are equal to CurveData.y1value values.
2740
2741        Justification:
2742        The name plate ratings are used as a reference.
2743
2744        Message:
2745        Invalid reactive capability curve data.
2746
2747        Usage: #IGMRuleSet
2748
2749   Rule: CurveXValues  Level: 3  Severity: WARNING
2750
2751        Details:
2752        For every instance of cim:CurveData, for which the cim:CurveData.Curve
2753        refers to a cim:ReactiveCapabilityCurve, the cim:CurveData.xvalue shall
2754        be different, e.g. in the case of two cim:CurveData called CD1 and CD2 the
2755        following shall give a warning when CD1.xvalue = CD2.xvalue.
2756
2757        Justification:
2758        All x values in a reactive capability curve
2759        shall differ for the curve to be meaningful.
2760
2761        Message:
2762        Some points in the reactive capability curve have the same x value.
2763
2764        Usage: #IGMRuleSet
2765
2766
2767   Rule: RCCXValues2  Level: 3  Severity: ERROR
2768
2769        Details:
2770        For a cim:SynchronousMachine with a cim:ReactiveCapabilityCurve the number of
2771        cim:CurveData instances depends on the attribute cim:SynchronousMachine.type
2772        as follows
2773        - condenser, one cim:CurveData instance with cim:CurveData.xvalue = 0.
2774        - generator or generatorOrCondenser, at least two cim:CurveData instances with
2775          cim:CurveData.xvalue greater or equal 0.
2776        - motor or motorOrCondenser, at least two cim:CurveData instances with
2777          cim:CurveData.xvalue less or equal 0.
2778        - generatorOrMotor or generatorOrCondenserOrMotor, at least three cim:CurveData
2779          instances with at least
2780          one having cim:CurveData.xvalue greater or equal 0 and
2781          and one having cim:CurveData.xvalue less or equal 0.
2782
2783        Justification:
2784        A cim:ReactiveCapabilityCurve for a Pump Storage unit shall have
2785        at least three curve points. A cim:SynchronousMachine operating as
2786        either motor or generator shall have at least two curve points. A
2787        cim:SynchronousMachine operating as condenser shall have at least one curve point.
2788
2789        Message:
2790        Invalid number of curve points in reactive capability curve data.
```

```
2791
2792          Usage: #IGMRuleSet
2793
2794    Rule: RCCXValues3  Level: 3  Severity: ERROR
2795
2796          Details:
2797          For each instance of cim:ReactiveCapabilityCurve, all instances of cim:CurveData
2798          shall have cim:CurveData.xvalue that is
2799          1) greater than or equal to the cim:GeneratingUnit.minOperatingP, and
2800          2) less than or equal to the cim:GeneratingUnit.maxOperatingP .
2801          cim:GeneratingUnit.minOperatingP    and    cim:GeneratingUnit.maxOperatingP    are
2802          attributes of the cim:GeneratingUnit associated with the cim:SynchronousMachine to
2803          which the cim:ReactiveCapabilityCurve applies.
2804
2805          Justification:
2806          A cim:ReactiveCapabilityCurve must stay within the maximum capability of the unit.
2807
2808          Message:
2809          Invalid reactive capability curve data for cim:SynchronousMachine.
2810
2811          Usage: #IGMRuleSet
2812
2813    Rule: RCCXValues4  Level: 3  Severity: WARNING
2814
2815          Details:
2816          For every instance of cim:ReactiveCapabilityCurve, each cim:CurveData instance
2817          must satisfy the following relation
2818          - x*x+y1*y1 LE ratedS*ratedS and x*x+y2*y2 LE ratedS*ratedS
2819          where
2820          - LE = less or equal
2821          - x= cim:CurveData.xvalue
2822          - y1 = cim:CurveData.y1value
2823          - y2 = cim:CurveData.y2value
2824          - ratedS = cim:RotatingMachine.ratedS * (1 + NUMERIC_TOLERANCE)
2825
2826          Justification:
2827          A cim:ReactiveCapabilityCurve must cover the full operating range.
2828
2829          Message:
2830          Invalid reactive capability curve data for cim:SynchronousMachine.
2831
2832          Usage: #IGMRuleSet
2833
2834    Rule: VSCYValues  Level: 3  Severity: ERROR
2835
2836          Details:
2837          For every instance of cim:CurveData, for which the cim:CurveData.Curve
2838          refers to a cim:VsCapabilityCurve, the cim:CurveData.y2value must
2839          be greater than cim:CurveData.y1value.
2840
2841          Justification:
2842          The name plate ratings are used as a reference.
2843
2844          Message:
2845          Invalid cim:VsCapabilityCurve data.
2846
```

```
2847          Usage: #IGMRuleSet
2848
2849    Rule: VSCXValues  Level: 3  Severity: ERROR
2850
2851          Details:
2852          For every instance of cim:CurveData, for which the cim:CurveData.Curve
2853          refers to a cim:VSCapabilityCurve, at least two instances of the
2854          cim:CurveData are associated.
2855
2856          Justification:
2857          A curve consists of at least two curve points.
2858
2859          Message:
2860          Invalid cim:VSCapabilityCurve data.
2861
2862          Usage: #IGMRuleSet
2863
2864    Rule: PhaseCodeGround  Level: 3  Severity: ERROR
2865
2866          Details:
2867          Multiple cim:ConductingEquipment-s are typically connected to the same
2868          cim:TopologicalNode via their cim:Terminal-s.
2869          The phase codes of the cim:Terminal-s of the following grounding equipment shall
2870    be N:
2871          - cim:PetersenCoil
2872          - cim:Ground
2873          - cim:GroundingImpedance
2874          Note that cim:GroundDisconnector will have phase code N at the two sides.
2875
2876          Justification:
2877          Ohms and Kirchoffs laws.
2878
2879          Message:
2880          Grounding equipment shall have phase code N only.
2881
2882          Usage: #IGMRuleSet
2883
2884
2885    Rule: ControlAreaInstance  Level: 3  Severity: ERROR
2886
2887          Details:
2888          Exactly one cim:ControlArea instance per IGM with following attributes
2889          must be defined:
2890          - cim:ControlArea.type is cim:ControlAreaTypeKind.Interchange
2891          - an entsoe:IdentifiedObject.energyIdentCodeEic shall be one of the codes defined
2892    in the QoCDC Reference Data document in column “RegionEic”.
2893
2894          Justification:
2895          The cim:ControlArea of type interchange is the model equivalent of
2896          a SchedulingArea.
2897
2898          Message:
2899          cim:ControlArea instance of type cim:ControlAreaTypeKind.Interchange is missing or
2900    does not have correct entsoe:IdentifiedObject.energyIdentCodeEic.
2901
2902          Usage: #IGMRuleSet
```

```
Rule: DCEquipmentContainerMapping  Level: 3  Severity: ERROR

      Details:
      For each cim:DCConverterUnit and cim:DCLine instance the attribute
entsoe:IdentifiedObject.energyIdentCodeEic is required. The third character of the EIC
code shall be 'T'.

      Justification:
      The mapping of reference schedules for HVDC links is done via
      the EIC T codes. The EIC T code is also used to identify DC equipment
      containers that belong to the same HVDC pole.

      Message:
      EIC code for cim:DCConverterUnit or cim:DCLine is either not provided or it is not
a 'T' code.

      Usage: #IGMRuleSet

Rule: RCandTCCcontrollingObjects  Level: 3  Severity: WARNING

      Details:
      A cim:RegulatingControl or cim:TapChangerControl shall have at least one
      controlling object. The cardinality
      - cim:RegulatingControl[0..1]-[0..*]cim:RegulatingCondEq
      - cim:TapChangerControl[0..1]-[0..*]cim:TapChanger
      are currently allowing no controlling objects.

      Justification:
      A cim:RegulatingControl or cim:TapChangerControl without controlling objects
      cannot perform control.
      It is important for IGMs quality and CGM creation process to indicate
      these occurrences.

      Message:
      cim:RegulatingControl or cim:TapChangerControl without controlling objects.

      Usage: #IGMRuleSet

Rule: SMRatedSunrealistic  Level: 3  Severity: WARNING

      Details:
      If a cim:SynchronousMachine has a rated power way beyond the specified
      active and reactive limit values or way outside the reactive capability curve
      the rated power value is not realistic.
      A EQ_RATEDS_REASONABILITY_FACTOR (RSRF) is used to determine if a rated power
      is reasonable.
      To be realistic and reasonable the cim:RotatingMachine.ratedS shall if an active
      or reactive power limit is present be less than
      - max(abs(cim:SynchronousMachine.minQ),
          abs(cim:SynchronousMachine.maxQ),
          abs(cim:GeneratingUnit.minOperatingP,
          abs(cim:GeneratingUnit.maxOperatingP))*RSRF
      - max(abs(CurveData.xvalue),
          abs(CurveData.y1value),
          abs(CurveData.y2value))*RSRF
```

2959 for all x, y1 and y2 values.
2960
2961 Justification:
2962 Rated powers may be given a large and unrealistic value that will impact other
2963 rules which may result in erroneous reporting by them.
2964
2965 Message:
2966 Unrealistic cim:RotatingMachine.ratedS specified.
2967
2968 Usage: #IGMRuleSet
2969
2970 Rule: TargetDeadbandOutOfRange Level: 3 Severity: WARNING
2971
2972 Details:
2973 If the cim:RegulatingControl.targetDeadband has a value similar to the
2974 cim:RegulatingControl.targetValue this means that it has no effect and
2975 that the cim:RegulatingControl is in practice disabled. Disabling a
2976 cim:RegulatingControl this way shouldn't be used, instead use the
2977 cim:RegulatingControl.enabled flag.
2978 cim:RegulatingControl.targetDeadband/EQ_DB_REASONABILITY_FACTOR
2979 should be less than the cim:RegulatingControl.targetValue.
2980 With a value of 2 for the EQ_DB_REASONABILITY_FACTOR this means that
2981 if the cim:RegulatingControl.targetDeadband is greater than twice the
2982 cim:RegulatingControl.targetValue this means that the target will always stay
2983 inside the dead band.
2984 The rule is only activated when cim:RegulatingControl.discrete="true" and
2985 cim:RegulatingControl.enabled="true".
2986
2987 Justification:
2988 Using other ways than cim:RegulatingControl.enabled flag shouldn't be used.
2989
2990 Message:
2991 cim:RegulatingControl has been potentially disabled with a large
2992 cim:RegulatingControl.targetDeadband.
2993
2994 Usage: #IGMRuleSet
2995
2996 Rule: WindingConnectionAngle Level: 3 Severity: WARNING
2997
2998 Details:
2999 The cim:PhaseTapChangerAsymmetrical.windingConnectionAngle attribute in real
3000 grids can only have the following values:
3001 - +/-150;
3002 - +/-120;
3003 - +/-90;
3004 - +/-60;
3005 - +/-30.
3006 Values can be expressed as integer or float. Non-zero decimals are not allowed in
3007 case the value is expressed as float.
3008 Justification:
3009 Asymmetrical phase tap changers are built for specific connection angles.
3010
3011 Message:
3012 cim:PhaseTapChangerAsymmetrical.windingConnectionAngle value is not
3013 one of the defined values.
3014

```
3015        Usage: #IGMRuleSet
3016
3017    Rule: VoltageLimitDirection  Level: 3  Severity: WARNING
3018
3019        Details:
3020        A cim:VoltageLimit should be specified with a direction high or low, i.e. the
3021        cim:OperationalLimitType.direction value should be one of
3022        - cim:OperationalLimitDirectionKind.high
3023        - cim:OperationalLimitDirectionKind.low
3024
3025        Justification:
3026        If the direction is missing it is not possible to check the voltage value.
3027
3028        Message:
3029        cim:OperationalLimitType.direction is either 1) not provided or 2) it is not set
3030    to cim:OperationalLimitDirectionKind.high or cim:OperationalLimitDirectionKind.low.
3031
3032        Usage: #IGMRuleSet
3033
3034    Rule: VoltageLimitsConsistency  Level: 3  Severity: WARNING
3035
3036        Details:
3037        cim:VoltageLimit within a given cim:OperationalLimitSet with direction
3038        cim:OperationalLimitDirectionKind.high should be
3039        greater than cim:VoltageLimit with direction
3040        cim:OperationalLimitDirectionKind.low.
3041
3042        Justification:
3043        cim:VoltageLimit not consistent with the specified direction are meaningless.
3044
3045        Message:
3046        cim:VoltageLimit values are not consistent with the specified directions.
3047
3048        Usage: #IGMRuleSet
3049
3050    Rule: FlowLimitsDirectionConsistency  Level: 3  Severity: WARNING
3051
3052        Details:
3053        Branch flow limits cim:CurrentLimit, cim:ApparentPowerLimit and
3054        cim:ActivePowerLimit should have a cim:OperationalLimitType.direction with value
3055        cim:OperationalLimitDirectionKind.absoluteValue.
3056
3057        Justification:
3058        Branch flow can go in both directions on the branch. Hence the direction should be
3059        specified as an absoluteValue.
3060
3061        Message:
3062        Branch flow limits with other direction than absoluteValue.
3063
3064        Usage: #IGMRuleSet
3065
3066    Rule: AsymmetricalEquivalent  Level: 3  Severity: WARNING
3067
3068        Details:
3069        cim:EquivalentBranch with EquivalentBranch.r not equal to EquivalentBranch.r21 or
3070        EquivalentBranch.x not equal to EquivalentBranch.x21 should not be used.
```

```
3071
3072        Justification:
3073        Equivalents with different impedance in different directions may result in poor
3074        convergence, hence reporting the difference support error tracing in data.
3075
3076        Message:
3077        cim:EquivalentBranch with asymmetrical impedances.
3078
3079        Usage: #IGMRuleSet
3080
3081
3082    Rule: PositiveTransformerB  Level: 3  Severity: WARNING
3083
3084        Details:
3085        Two-winding transformer with positive shunt (cim:PowerTransformerEnd.b > 0)
3086        that are not equivalenced (cim:Equipment.aggregate = false)
3087        shouldn't have positive PowerTransformerEnd.b.
3088
3089        Justification:
3090        Two winding transformers are reactive and should not have
3091        positive cim:PowerTransformerEnd.b.
3092
3093        Message:
3094        Two winding transformer with positive shunt.
3095
3096        Usage: #IGMRuleSet
3097
3098    Rule: SubLoadAreaMissing  Level: 3  Severity: ERROR
3099
3100        Details:
3101        The reference cim:LoadGroup->cim:SubLoadArea is required. The class cim:LoadGroup
3102        in in EQ core while cim:SubLoadArea is in operation. Hence a BB model using
3103        classes cim:ConformLoad and cim:NonConformLoad will get an error if cim:SubLoadArea
3104        instances are missing. As a CGM may contain both NB and BB models the
3105        cardinality for the BB models need to be 0..1 but for the NB models 1.
3106        This is solved by making the reference cim:LoadGroup->cim:SubLoadArea optional
3107        and have this rule checking that NB models do have the references.
3108
3109        Justification:
3110        This is a bug fix of CGMES2.4.15.
3111
3112        Message:
3113        The reference cim:LoadGroup->cim:SubLoadArea is missing.
3114
3115        Usage: #IGMRuleSet
3116
3117    Rule: EnergyAreaMissing  Level: 3  Severity: ERROR
3118
3119        Details:
3120        The reference cim:ControlArea->cim:EnergyArea is required for NB models
3121        but not for BB models.
3122
3123        Justification:
3124        Required for NB models according to diagram note in CGMES2.4.15.
3125
3126        Message:
```

```
      The reference cim:ControlArea->cim:EnergyArea is missing.

      Usage: #IGMRuleSet

Rule: GeneratingUnitSM  Level: 3  Severity: ERROR

      Details:
      A cim:GeneratingUnit or any of its subclasses is not allowed to have more
      than one cim:RotatingMachine.

      Justification:
      Having more than one cim:RotatingMachine with a cim:GeneratingUnit will make
      active and reactive limits dynamically dependent of the number of operational
      cim:RotatingMachine-s which makes scheduling difficult as this information
      is missing.

      Message:
      A cim:GeneratingUnit is not allowed to have more than one cim:RotatingMachine.

      Usage: #IGMRuleSet
```

6 LEVEL 4 VALIDATION: MODEL ASSEMBLY

6.1 INTRODUCTION

Model assembly refers to the process of fulfilling the dependencies as specified in the file headers of instance files, starting with the official ENTSO-E EquipmentBoundary and TopologyBoundary instances, followed by the EQ, SSH, TP and SV instances of a Modelling Authority or multiple Modelling Authorities. Note that the meta data <md:Model.DependentOn> statements describe which instance models were used when the IGM was assembled, but the official ENTSO-E boundary files[8] are always to be used for the validation and merging process, instead of any other referenced boundary set.

In model instances, rdf:ID values always refer to unique objects within in that particular model instance file, whereas rdf:about values refer to objects that are unique in the namespace. As descriptive information is provided in multiple, associated files or model parts, it needs to be checked if all the mandatory data is complete for all identified objects.

In model instances, rdf:resource attributes always refer to objects that have been defined via a rdf:ID or rdf:about previously in the same model instance or any other model instance that is part of the assembly. It is intended to define an association to this object, acting as a pointer.

A dangling reference is just like a broken link on the web. In a model assembly it's a reference to an identified object that should have a description in the assembly and, simply, doesn't.

[8] The official boundary set can be recognized via the description field in the header. The most recent version is to be used at all times (highest version number)

6.2 FILE HEADERS – DEPENDENCIES

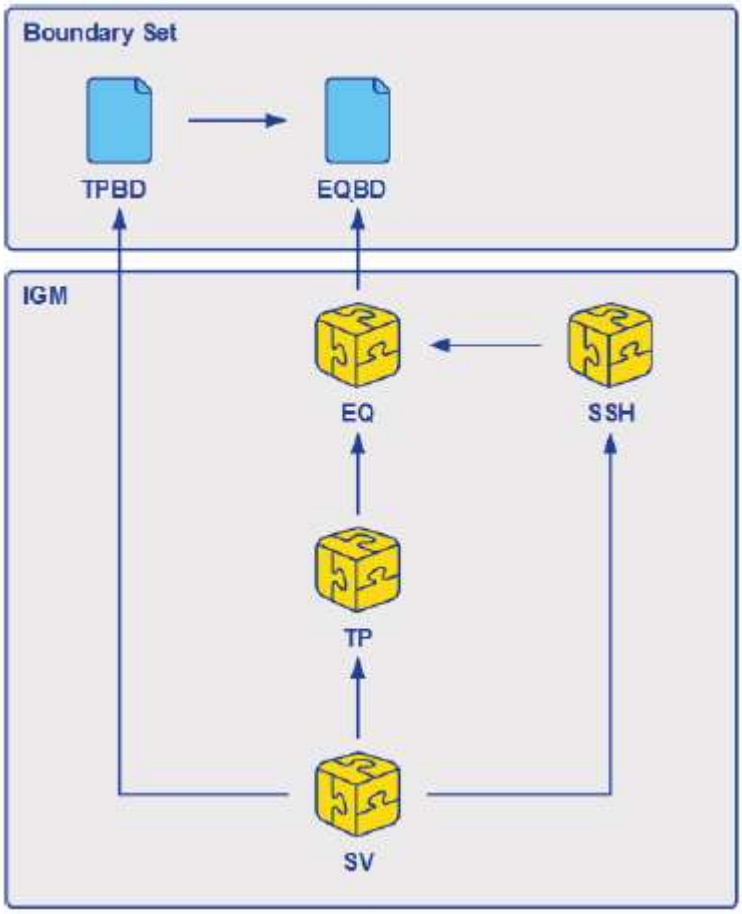


Figure 7 Dependencies of CGMES model instances

Figure 7 is an easier to read version of the figure from PROF10 in IEC TS 61970-600-1 Ed 1.

The references in Figure 7 are required and rules for them has been implemented in section 6.4. IGMs may include references between CIMXML files other than the ones in Figure 7, such references are ignored.

CGMES Individual Grid Models and Common Grid Models are exchanged in separate EQ instance files (model parts) which may be reused for multiple scenario times. Instance files may contain objects with associations to objects which will be packaged in a different instance file. This situation means that the instance file by itself is 'incomplete' – it may have dangling references and cannot be used except when combined with one or more other instance file as specified in the file header dependencies. When this occurs, validation for completeness can only be performed when all the parts are present. The md:Model.DependentOn role with multiplicity [0..*] in a CIMXML file header is used to list other CIMXML files that this CIMXML file depend on. This is explained in Annex C and rule PROF10 of TS 61970-600-1:2017.

For the Common Grid Model process, the boundary set is considered as reference data.

6.3 FILE HEADERS – GENERAL REQUIREMENTS

Model exchange typically involves the exchange of a collection of CIMXML files (model parts), each of which contains instance data, referred to as a model, and a header. The structure and semantics of each model are described by a profile, which is not included in the exchanged data. The exchange of CIMXMLfiles is governed by a collection of profiles described in IEC TS 61970-600 parts 1 and 2.

A header section describes the content of the model section contained in the CIMXML file e.g. the date the model was created, description etc. The header may also identify other models and their relationship to them. Such information is important when the models are part of a work flow where, for example, the models have relations to each other, e.g. a Supersedes and/or DependentOn referring to other CIMXML files. The Model class that has the above relations that are described in IEC 61970-552 Ed2.

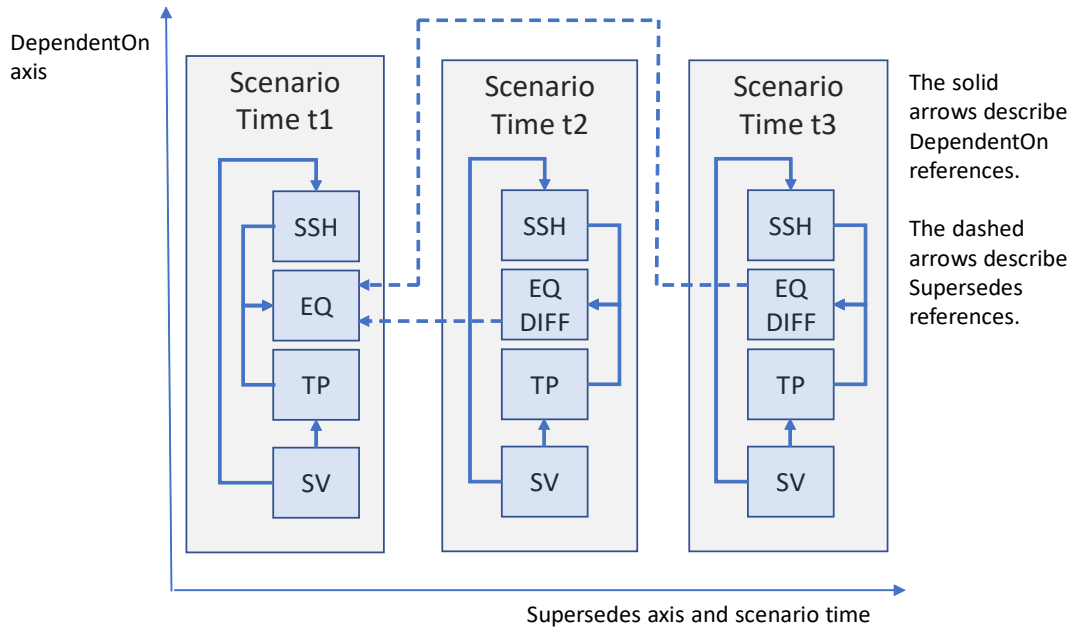


Figure 8 Use of DependentOn and Supersedes in IGMs

Supersedes is restricted to the use cases:

- Update of the same limit values multiple times.
- Complete replacement of SSH files at CGM creation.

The relation between IGM and CGM files is shown by the example in Figure 9.

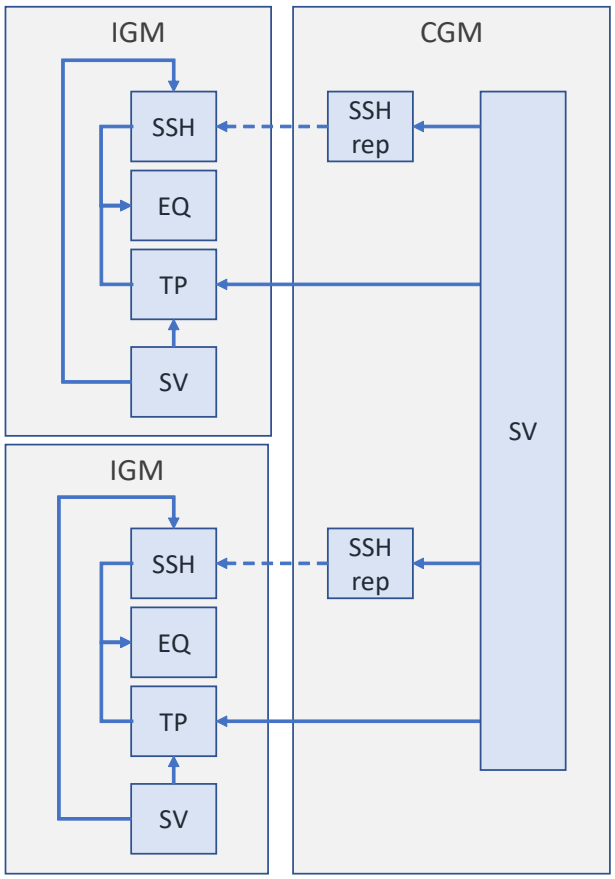


Figure 9 Example of relations between IGM and CGM files

Figure 9 show two IGMs to the left and one CGM that is merging the IGMs to the right.

The header section shall always be the first element in a CIMXML document. The header section elements are:

- FullModel element
- DifferenceModel element

The data in the model section following the header is defined by one or more profiles listed within the header.

Elements or objects in a CIMXML file may have references to elements (objects or resources) in other CIMXML documents. The references are exemplified in Figure 8 and Figure 9 above.

To use a CIMXML difference file it must be applied to the CIMXML file it Supersedes, i.e. the difference description in the DifferenceModel element is applied to the superseded CIMXML file and the operations to apply are

- Addition of new objects
- Deletion of existing objects
- Update of attribute values

These operations result in a new CIMXML file that contains the combination of superseding and the superseded files as shown in Figure 10

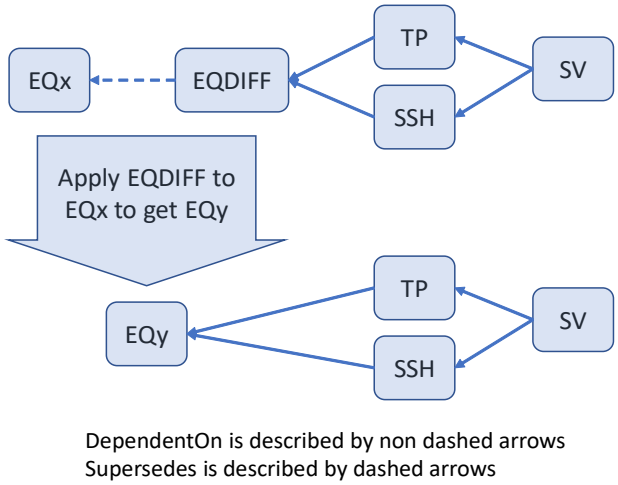


Figure 10 Application of DIFF files

In Figure 10 the FullModel EQ file EQx is Superseded by the difference file EQDIFF. Applying the differences in EQDIFF result in a new EQ file EQy. EQy has the same meta data as EQDIFF which

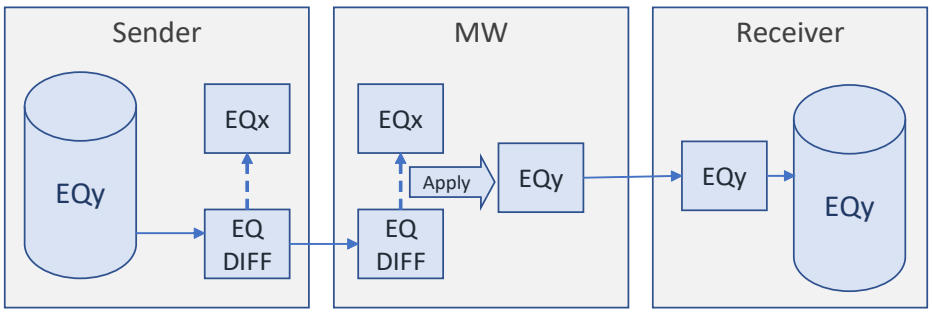


Figure 11 Applying the EQDIFF at the middleware

In Figure 11 the EQDIFF file is transferred to the middleware (OPDE) where it is applied to the Superseded EQx file to create the EQy file. This is required also for the validation of the EQDIFF as the validation can only be made on the EQy file, not on the EQDIFF alone.

6.4 VALIDATION RULES

```
Rule: TPBD->EQBD  Level: 4  Severity: ERROR

      Details:
      Every TPBD file shall have an 'md:Model.DependentOn'
      reference to the EQBD file.

      Justification:
      IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
      IDs of the dependent files at the time of the export".
      IEC TS 61970-600-1:2017, requirement PROF10.

      Message:
      Invalid md:Model.DependentOn statement(s) in TPBD.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: EQ->EQBD  Level: 4  Severity: ERROR

      Details:
      Every EQ file shall have an 'md:Model.DependentOn'
      reference to the EQBD file that was used for the
      serialization.

      Justification:
      IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
      IDs of the dependent files at the time of the export".
      IEC TS 61970-600-1:2017, requirement PROF10.

      Message:
      Invalid md:Model.DependentOn statement(s) in EQ.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: TP->EQ,TP->EQDIFF  Level: 4  Severity: ERROR

      Details:
      Every TP file shall have an
      'md:Model.DependentOn' reference to a EQ or EQDIFF file.
      Note: This is a minimum requirement so more references may be present.

      Justification:
      IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
      IDs of the dependent files at the time of the export".
      IEC TS 61970-600-1:2017, requirement PROF10.

      Message:
      Invalid md:Model.DependentOn statement(s) in TP.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: SSH->EQ,SSH->EQDIFF  Level: 4  Severity: ERROR

      Details:
```

```
3293          Every SSH file shall have an
3294          'md:Model.DependentOn' reference to a EQ or EQDIFF file.
3295          Note: This is a minimum requirement so more references may be present.
3296
3297          Justification:
3298          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3299          IDs of the dependent files at the time of the export".
3300          IEC TS 61970-600-1:2017, requirement PROF10.
3301
3302          Message:
3303          Invalid md:Model.DependentOn statement(s) in SSH.
3304
3305          Usage: #IGMRuleSet #CGMRuleSet
3306
3307    Rule: DY->EQ,DY->EQDIFF  Level: 4  Severity: ERROR
3308
3309          Details:
3310          Every DY file shall have an
3311          'md:Model.DependentOn' reference to a EQ or EQDIFF file.
3312          Note: This is a minimum requirement so more references may be present.
3313
3314          Justification:
3315          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3316          IDs of the dependent files at the time of the export".
3317          IEC TS 61970-600-1:2017, requirement PROF10.
3318
3319          Message:
3320          Invalid md:Model.DependentOn statement(s) in DY.
3321
3322          Usage: #IGMRuleSet #CGMRuleSet
3323
3324    Rule: SV->SSH,SV->TP,SV->TPBD  Level: 4  Severity: ERROR
3325
3326          Details:
3327          Every SV file shall have 'md:Model.DependentOn' references to the files
3328          - SSH input files to the power flow calculation.
3329          - TP files with the power flow busses used in the power flow calculation.
3330          - TPBD files with the power flow busses in the boundary
3331          Note: This is a minimum requirement so more references may be present.
3332
3333          Justification:
3334          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3335          IDs of the dependent files at the time of the export".
3336          IEC TS 61970-600-1:2017, requirement PROF10.
3337
3338          Message:
3339          Invalid md:Model.DependentOn statement(s), SV must have reference to TP, SSH
3340          and TPBD (used as input data for the power flow calculations).
3341
3342          Usage: #IGMRuleSet #CGMRuleSet
3343
3344    Rule: GL->EQ,GL->EQBD  Level: 4  Severity: ERROR
3345
3346          Details:
3347          Every GL model file has 'md:Model.DependentOn'
3348          references to the EQ model file and EQBD model file that
```

```
3349          were used for the serialization. The reference to the EQ model file is required
3350          and EQBD model file is optional.
3351          Note: This is a minimum requirement so more references may be present.
3352
3353          Justification:
3354          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3355          IDs of the dependent files at the time of the export".
3356          IEC TS 61970-600-1:2017, requirement PROF10.
3357
3358          Message:
3359          Invalid md:Model.DependentOn statement(s), GL must have reference to EQ.
3360
3361          Usage: #IGMRuleSet #CGMRuleSet
3362
3363    Rule: DL->EQ,DL->EQDIFF,DL->TP,DL->DY  Level: 4  Severity: ERROR
3364
3365          Details:
3366          Every DL file shall have 'md:Model.DependentOn'
3367          references to the EQ or EQDIFF file, the TP file and to
3368          the DY file that were used for the serialization. The
3369          reference to the EQ model file is required and the references to
3370          TP and DY model files are optional.
3371          Note: This is a minimum requirement so more references may be present.
3372
3373          Justification:
3374          IEC TS 61970-600-1:2017, requirement HREF2: "Dependent IDs refer to
3375          IDs of the dependent files at the time of the export".
3376          IEC TS 61970-600-1:2017, requirement PROF10.
3377
3378          Message:
3379          Invalid md:Model.DependentOn statement(s), DL must have reference to EQ.
3380
3381          Usage: #IGMRuleSet #CGMRuleSet
3382
3383    Rule: EQDIFF->EQ  Level: 4  Severity: ERROR
3384
3385          Details:
3386          Every EQDIFF file shall only have a md:Model.Supersedes
3387          references to the EQ file it updates as it is not correct to use
3388          md:Model.DependentOn for a CIMXML file that replaces or supersedes another.
3389          The elements of the following types are allowed in the EQDIFF document
3390          - cim:VoltageLimit
3391          - cim:CurrentLimit
3392          - cim:ActivePowerLimit
3393          - cim:ApparentPowerLimit
3394          This rule restricts use of difference models and is CGM_BP specific.
3395
3396          Justification:
3397          IEC TS 61970-600-1:2017 annex C.2.
3398          EMF meeting decision in Rome 2018-10-05.
3399
3400          Message:
3401          Invalid md:Model.Supersedes statement(s), reference to EQ only allowed.
3402
3403          Usage: #IGMRuleSet #CGMRuleSet
3404
```

```
Rule: EQDIFFOperationalLimit  Level: 4  Severity: ERROR

      Details:
      An EQDIFF file is only allowed to contain subclasses of OperationalLimit.
      This is a temporary solution for exchange of limit values in EQ
      that in the future will be in SHH.
      This rule restricts use of difference models and is CGM_BP specific.

      Justification:
      IEC TS 61970-600-1:2017 annex C.2.
      EMF meeting decision in Rome 2018-10-05.

      Message:
      Not allowed CIM class in EQDIFF file.

      Usage: #IGMRuleSet

Rule: DanglingReference  Level: 4  Severity: ERROR

      Details:
      The CGMES requires that at the receiving end of the exchange all
      references in the instance files pointing to instance files from
      other profiles which are part of the exchange should be satisfied.
      Therefore, the complete set of instance files necessary for the grid
      model must have fulfilled references (no dangling references are allowed).
      The mRID specified in every rdf:resource attribute in the assembly of
      cimxml instance files has been defined in an existing rdf:ID, rdf:about
      or enumeration.

      Justification:
      See IEC TS 61970-600-1:2017 Requirement FBOD4.

      Message:
      Dangling reference found.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: IncorrectAttributeOrRoleCard  Level: 4  Severity: ERROR

      Details:
      All mandatory attributes and associations must be provided for the
      assembled model  according to cardinalities given by profiles specified
      in md:Model.profile for each of the assembled CIMXML files.

      Justification:
      See IEC TS 61970-600-1:2017 Requirements PROF5 and PROF7.

      Message:
      Cardinality violated for attribute or role,
      too many or too few values or references provided.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: CgmSvSshVersionMismatch  Level: 4  Severity: ERROR

      Details:
```

A CGM will have updated SSH files (referencing to original data by Supersede statement) for each IGM and a single SV file
with the complete solution for the included IGMs. The updated SSH CIMXML files and the resulting CIMXML SV file should have:
- the same md:Model.scenarioTime.
- a new md:Model.version number that is the same for the SV and SSH CIMXML files.
Note: Section 6.6 of the ENTSO-E CGM Building process Implementation guide AC part, version 1.3, 13 May 2020 provides details on IGM substitution and rules related to md:Model.scenarioTime.

Justification:
Versioning of CGM is important for sustainable CGM building process.

Message:
Different fileVersion or effectiveDateTime in SSH and SV from CGM.

Usage: #CGMRuleSet

7 LEVEL 5 VALIDATION: CONSISTENCY OF ASSEMBLED MODEL

7.1 INTRODUCTION

In this level, consistency between equipment characteristics in EQ and scenario data from the other instance data files is validated.

7.2 VALIDATION RULES

Rule: GeographicalRegionBD Level: 5 Severity: WARNING

Details:
cim:GeographicalRegion-s should be agreed on by modelling authorities and be described in the equipment boundary.

Justification:
cim:GeographicalRegion is used to organise equipment geographically and regions that corresponds to a network model managed by a TSO which is also the ModelingAuthority for the network.

Message:
cim:GeographicalRegion from the boundary is not used.

Usage: #IGMRuleSet

Rule: GeographicalRegion Level: 5 Severity: ERROR

Details:
An IGM shall have a single cim:GeographicalRegion. cim:SubGeographicalRegion-s in an IGM shall refer to a single cim:GeographicalRegion.

Justification:

cim:GeographicalRegion is used to organise equipment geographically and regions that corresponds to a network model managed by a TSO which is also the ModelingAuthority for the network.
Each IGM shall be described by one cim:GeographicalRegion.
See also IEC TS 61970-600-1 E.13.

Message:
More than one GeographicalRegion in IGM or cim:SubGeographicalRegion-s refer to multiple cim:GeographicalRegion-s.

Usage: #IGMRuleSet

Rule: LineContainment Level: 5 Severity: ERROR

Details:
For every instance of cim:ACLineSegment, the cim:Equipment.EquipmentContainer referred to, if provided, must be of type cim:Line.

Justification:
See Figure 15 (diagram Core notes) and section 6.9.16 of IEC TS 61970-600-2.

Message:
cim:ACLineSegments can only be contained in a cim:Line.

Usage: #IGMRuleSet

Rule: EquivalentInjectionContainment Level: 5 Severity: ERROR

Details:
Every cim:EquivalentInjection shall be contained by a
- cim:VoltageLevel if not in a boundary point.
- If in a boundary point, preferably it is contained in a cim:Line or not contained at all with provided association to cim:BaseVoltage.

Justification:
All equipment shall be contained, also cim:EquivalentInjection, but as it is allowed not to have cim:EquivalentInjection contained this is allowed for backwards compatibility.
See also IEC TS 61970-600-2 6.7.6.

Message:
cim:EquivalentInjection containment error.

Usage: #IGMRuleSet

Rule: DCLineContainment Level: 5 Severity: ERROR

Details:
For every instance of cim:DCLineSegment, the cim:Equipment.EquipmentContainer referred to, must be of type cim:DCLine. In the case of modelling back to back configuration the association shall point to EquipmentContainer of type cim:Substation. Missing containment is not allowed.

```
3564          Justification:
3565          See section 6.3.15 of IEC TS 61970-600-2
3566
3567          Message:
3568          cim:DCLineSegment must be contained in a cim:DCLine or a cim:Substation.
3569
3570          Usage: #IGMRuleSet
3571
3572
3573    Rule: BaseVoltageNotInBoundary  Level: 5  Severity: WARNING
3574
3575          Details:
3576          All cim:BaseVoltages should be agreed on by modeling authorities and
3577          be in the boundary.
3578          If a matching base voltage is already in the boundary it
3579          should be used.
3580          If a matching base voltage is not in the boundary, consider
3581          to add it in the boundary so that it can be reused by others.
3582
3583
3584          Justification:
3585          An agreement on the base voltages is required to get interoperability.
3586          Rule added at CGM_BP meeting in Zagreb 2019-05-23.
3587
3588          Message:
3589          cim:BaseVoltage not in boundary.
3590
3591          Usage: #IGMRuleSet
3592
3593
3594    Rule: SVCVoltage  Level: 5  Severity: ERROR
3595
3596          Details:
3597          The association end cim:RegulatingCondEq.RegulatingControl is required.
3598    cim:RequlatingControl.targetValue shall be greater than zero if
3599    cim:RequlatingControl.mode is RegulatingControlModeKind.voltage.
3600    The attributes cim:StaticVarCompensator.sVCControlMode and
3601    cim:StaticVarCompensator.voltageSetPoint are ignored at both model validation and control
3602    logic of the SVC.
3603
3604          Justification:
3605          The reactive power output of the SVC is proportional to the
3606          difference between the voltage at the regulated bus and the voltage
3607          setpoint. When the regulated bus voltage is equal to the voltage
3608          setpoint, the reactive power output is zero.
3609          RequlatingControl is used as it has capabilities missing from SVC,
3610          e.g. the controlled point.
3611          See IEC TS 61970-600-2:2017, section 6.9.44.
3612
3613          Message:
3614          cim:RegulatingCondEq.RegulatingControl is not provided or
3615    cim:RequlatingControl.targetValue is not greater than zero.
3616
3617
3618          Usage: #IGMRuleSet
3619
```

```
Rule: TapChangerNeutralU  Level: 5  Severity: ERROR

      Details:
      The cim:TapChanger.neutralU shall be the same as cim:PowerTransformerEnd.ratedU.

      Justification:
      See section E.2.2. of IEC TS 61970-600-1:2017.

      Message:
      The neutralU differs from ratedU.

      Usage: #IGMRuleSet

Rule: ControlLinkedToTopology  Level: 5  Severity: WARNING

      Details:
      The controlled cim:Terminal at a cim:RegulatingControl (RC) or
      cim:TapChangerControl (TCC) must be linkedto a cim:TopologicalNode (TN).
      In case cim:Switch cim:Terminals are not included in TP and if the
      controlled point is a cim:Switch cim:Terminal the controlled point is lost.
      The cardinality for cim:Terminal.TopologicalNode is 1 so it is required,
      hence all cim:Terminals must be present in TP regardless of the type of
      conducting equipment, it is linked to.
      This rule shouldn't be needed if all cim:Terminals where present in TP.

      Justification:
      If a RC or TCC is not linked to a TN the changes in the control variables will not
      affect the target value in the power flow calculation.
      See section E.12 of IEC TS 61970-600-1:2017.

      Message:
      Terminal controlled by cim:RegulatingControl or cim:TapChangerControl is not
      linked to a cim:TopologicalNode.

      Usage: #IGMRuleSet

Rule: BranchBaseVoltage  Level: 5  Severity: ERROR

      Details:
      Every instance of cim:ACLineSegment, cim: SeriesCompensator or cim:EquivalentBranch
      must have an association cim:ConductingEquipment.BaseVoltage.

      Note: PowerTransformerEnd already has required association with
      cim:TransformerEnd.BaseVoltage.

      Justification:
      See section 6.7.6, 6.10.42, 6.12.2 and 6.10.2 of IEC TS 61970-600-2.

      Message:
      Either cim:ACLineSegment, cim:EquivalentBranch, or cim:SeriesCompensator    has
no BaseVoltage.

      Usage: #IGMRuleSet

Rule: EquivalentInjectionControlEnabled  Level: 5  Severity: WARNING
```

```
3676        Details:
3677        Boundary cim:EquivalentInjections should have control disabled,
3678        cim:EquivalentInjection.regulationCapability should be false, and
3679  cim:EquivalentInjection.regulationStatus shall also be set to false.
3680        An cim:EquivalentInjection may have control enabled only if it represents an
3681        HVDC converter.
3682        cim:EquivalentInjections that are result of network reduction may have control
3683        enabled, if so realistic reactive power limits shall be provided.
3684        Note: An HVDC Boundary Point has a cim:IdentifiedObject.description
3685        attribute equal to 'HVDC'.
3686
3687        Justification:
3688        Excessive reactive resources do not properly reflect power system behaviour.
3689
3690        Message:
3691        Boundary cim:EquivalentInjections representing AC networks should
3692        not control voltage.
3693
3694        Usage: #IGMRuleSet
3695
3696  Rule: NoLTCTapChangerControl  Level: 5  Severity: WARNING
3697
3698        Details:
3699        If cim:TapChanger.ltcFlag is false, no TapChangerControl object is
3700        referenced by cim:TapChanger.TapChangerControl.
3701
3702        Justification:
3703        See section E.9.3. of IEC TS 61970-600-1:2017.
3704
3705        Message:
3706        TapChangerControl found for TapChanger.step that cannot be changed under load.
3707
3708        Usage: #IGMRuleSet
3709
3710  Rule: SvTapStepInstances  Level: 5  Severity: ERROR
3711
3712        Details:
3713        A cim:SvTapStep instance is expected for all cim:TapChanger instances
3714        defined in EQ.
3715
3716        Justification:
3717        See section E.9.3. of IEC TS 61970-600-1:2017.
3718
3719        Message:
3720        Missing SvTapStep for TapChanger.
3721
3722        Usage: #IGMRuleSet #CGMRuleSet
3723
3724  Rule: SvPowerFlowInstances  Level: 5  Severity: ERROR
3725
3726        Details:
3727        cim:SvPowerFlow class is required to be instantiated for the following classes:
3728        - subclasses of the cim:RotatingMachine
3729        - subclasses of the cim:EnergyConsumer
3730        - cim:EquivalentInjection
3731        - cim:ExternalNetworkInjection
```

- cim:ShuntCompensator
- cim:StaticVarCompensator
- cim:EnergySource.

Justification:
See section 9.5.4 of IEC TS 61970-600-2.

Message:
Missing SvPowerFlow for Equipment.

Usage: #IGMRuleSet #CGMRuleSet

Rule: SvPowerFlowBranchInstances Level: 5 Severity: ERROR

Details:
The following shall conform:
1) For cim:TieFlow, which association end cim:TieFlow.ControlArea refers to a cim:ControlArea with cim:ControlArea.type equal to cim:ControlAreaTypeKind.Interchange, the association end cim:TieFlow.Terminal shall refer to a cim:Terminal of either cim:ACLineSegment, cim:PowerTransformer or cim:Switch and its subclasses. The cim:Terminal referenced by the association end cim:TieFlow.Terminal shall be associated with a boundary cim:TopologicalNode that conforms to item 2).
2) A boundary cim:TopologicalNode that is connected to an IGM shall have
- One cim:EquivalentInjection
- One of the following equipment: cim:ACLineSegment, cim:PowerTransformer or a retained cim:Switch (cim:Switch.retained=true) and its subclasses.

Justification:
See BPPL1 of IEC TS 61970-600-1:2017.
Normally, cim:EquivalentBranch-es result from a power system reduction process that depends on its state, e.g. connectivity. Therefore, cim:EquivalentBranch-es are not persistent over time as new ones may be created while previous ones deleted. Branches connected at the network boundary need to be well defined and unambiguously identifiable, as they are representing non-equivalent objects connected to a boundary point agreed between the two parties on a given border. The cim:EquivalentBranch is not meeting such criteria by nature hence, it shall not connect to a boundary point.

Message:
One of the following occurs: 1) A cim:TieFlow with a cim:TieFlow.Terminal referring to either a cim:Terminal that is not connected to a boundary cim:TopologicalNode or it is not a cim:Terminal of one of the following: cim:ACLineSegment, cim:PowerTransformer or a retained cim:Switch and its subclasses; 2) A boundary cim:TopologicalNode connected to the IGM that does not have one cim:EquivalentInjection and one of the following: cim:ACLineSegment, cim:PowerTransformer, or a retained cim:Switch and its subclasses.

Usage: #IGMRuleSet #CGMRuleSet

Rule: SvPowerFlowBranchInstances2 Level: 5 Severity: WARNING

Details:
Branches should have cim:SvPowerFlow instantiated at its cim:Terminals for the following branch classes:
- cim:SeriesCompensator
- cim:ACLineSegment

```
3788          - cim:PowerTransformer
3789          - cim:Switch where cim:Switch.retained is true.
3790
3791          Justification:
3792          The power flow result for branches cannot be reviewed without cim:SvPowerFlow.
3793          This is needed when solutions for the same IGM or CGM computed by different
3794          tools are compared.
3795          Note that computing the flows by scripts based on solved voltages may not
3796          give the same result as the original power flow.
3797
3798          Message:
3799          Missing cim:SvPowerFlow for branch.
3800
3801          Usage: #IGMRuleSet #CGMRuleSet
3802
3803    Rule: DisconnectedTerminal  Level: 5  Severity: ERROR
3804
3805          Details:
3806          If the associated cim:Terminal.connected status is false, the flow
3807          specified in the cim:SvPowerFlow.p and cim:SvPowerFlow.q shall be zero.
3808
3809          Justification:
3810          See section 9.5.4. of IEC TS 61970-600-2.
3811
3812          Message:
3813          Zero flow expected for disconnected terminal.
3814
3815          Usage: #IGMRuleSet #CGMRuleSet
3816
3817    Rule: TopologicalIslandInstance  Level: 5  Severity: ERROR
3818
3819          Details:
3820          In case a solved model is exchanged for a single MAS the state variables
3821          profile must include at least one instance of cim:TopologicalIsland.
3822
3823          Justification:
3824          See section E.6 of IEC TS 61970-600-1:2017.
3825
3826          Message:
3827          Missing cim:TopologicalIsland.
3828
3829          Usage: #IGMRuleSet #CGMRuleSet
3830
3831    Rule: SmallTopologicalIsland  Level: 5  Severity: WARNING
3832
3833          Details:
3834          A small cim:TopologicalIsland with TNs having zero voltage is in most cases
3835          meaningless and should not be exchanged.
3836          A cim:TopologicalIsland with three or fewer cim:TopologicalNodes is small.
3837
3838          Justification:
3839          A small cim:TopologicalIsland is typically not energized and does not contribute
3840          to the interconnected network solution. The number of three cim:TopologicalNodes
3841          as a small island is selected to catch disconnected three winding transformers.
3842
3843          Message:
```

```
3844          Small cim:TopologicalIsland found.
3845
3846          Usage: #IGMRuleSet #CGMRuleSet
3847
3848    Rule: SlackNode  Level: 5  Severity: WARNING
3849
3850          Details:
3851          For every cim:TopologicalIsland the
3852          cim:TopologicalIsland.AngleRefTopologicalNode should refer to the
3853          cim:TopologicalNode with a cim:SynchronousMachine having the highest
3854          cim:SynchronousMachine.referencePriority. The priority values are
3855          - 0 not included in slack node determination.
3856          - 1 is the highest.
3857          - 2 and on are decreasing priorities. If no cim:SynchronousMachine with
3858             cim:SynchronousMachine.referencePriority specified is available the
3859             cim:TopologicalIsland.AngleRefTopologicalNode can be set to any
3860             cim:TopologicalNode.
3861
3862          Justification:
3863          See section E.4 of IEC TS 61970-600-1:2017
3864          If different power flow solutions have the same angle reference
3865          for the same network solutions are easier to compare.
3866          If not, the linear offset is to be expected.
3867
3868          Message:
3869          A cim:SynchronousMachine with valid ReferencePriority exists
3870          but is not used for defining the angle reference node in topological island.
3871
3872          Usage: #IGMRuleSet #CGMRuleSet
3873
3874    Rule: SwitchTerminals  Level: 5  Severity: ERROR
3875
3876          Details:
3877          For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
3878          cim:GroundDisconnector, cim:LoadBreakSwitch and cim:ProtectedSwitch,
3879          it is not allowed to have its cim:Terminals connected to the
3880          same cim:ConnectivityNode.
3881
3882          Justification:
3883          See section E.17 of IEC TS 61970-600-1:2017.
3884
3885          Message:
3886          A switch cannot have its terminals connect the same cim:ConnectivityNode.
3887
3888          Usage: #IGMRuleSet
3889
3890    Rule: SwitchVL  Level: 5  Severity: ERROR
3891
3892          Details:
3893          For every instance of cim:Switch, cim:Breaker, cim:Disconnector,
3894          cim:GroundDisconnector, cim:LoadBreakSwitch and cim:ProtectedSwitch,
3895          it is not allowed to connect cim:ConnectivityNode or cim:TopologicalNode
3896          in different cim:VoltageLevels.
3897
3898          Justification:
3899          See section E.17 of IEC TS 61970-600-1:2017.
```

Message:
A cim:Switch cannot connect to cim:ConnectivityNodes or cim:TopologicalNodes in different cim:VoltageLevels.

Usage: #IGMRuleSet

Rule: SwitchTN1 Level: 5 Severity: ERROR

Details:
For every instance of cim:Switch, cim:Breaker, cim:Disconnector, cim:GroundDisconnector, cim:LoadBreakSwitch and cim:ProtectedSwitch, with cim:Switch.retained is true, its cim:Terminals shall be associated with different cim:TopologicalNodes.

Justification:
See section E.17 of IEC TS 61970-600-1:2017.

Message:
Retained cim:Switch cim:Terminals cannot be associated with the same cim:TopologicalNode.

Usage: #IGMRuleSet

Rule: SwitchOpenVsConnected Level: 5 Severity: ERROR

Details:
The attribute cim:ACDCTerminal.connected shall always be set to true for terminals of cim:Switch or its subclasses.

Justification:
A cim:Terminal has switching capability due to the attribute cim:ACDCTerminal.connected flag, a cim:Equipment can be disconnected with this flag. For cim:Switch-es this means it is possible to break the conducting path at three places:
- cim:ACDCTerminal.connected side 1 (cim:ACDCTerminal.sequenceNumber=1)
- cim:Switch.open
- cim:ACDCTerminal.connected side 2 (cim:ACDCTerminal.sequenceNumber=2)
Evaluating switch status then means inspecting the three flags for every switch.

Message:
cim:ACDCTerminal.connected is not set to true for a cim:Switch or its subclasses.

Usage: #IGMRuleSet

Rule: ParticipatingGeneratingUnit Level: 5 Severity: WARNING

Details:
This rule applies when generation slack is used.
cim:GeneratingUnit-s that pick-up mismatch shall have a cim:GeneratingUnit.normalPF greater than 0. At least one such unit is required in every electrical island.

Justification:
GeneratingUnits cannot pick-up mismatch if this data is unspecified.

Message:

```
3956          No GeneratingUnit with .normalPF greater than 0 in an island.
3957
3958          Usage: #IGMRuleSet
3959
3960    Rule: ControlOfAnotherIsland  Level: 5  Severity: WARNING
3961
3962          Details:
3963          A cim:RegulatingControl or cim:TapChangerControl should not control a
3964          cim:TopologicalNode in another cim:TopologicalIsland than its
3965          controlling equipment is located.
3966          The rule is applied for cim:RegulatingControl.enabled equal true. In addition, the
3967          rule applies to objects only within the IGM as references to objects in another
3968          MAS will be reported as dangling references.
3969
3970          Justification:
3971          There is no feedback loop to the control in this case.
3972
3973          Message:
3974          A controlled cim:TopologicalNode is in another cim:TopologicalIsland
3975          than the controlling equipment.
3976
3977          Usage: #IGMRuleSet #CGMRuleSet
3978
3979    Rule: TapChangerTargetRange  Level: 5  Severity: WARNING
3980
3981          Details:
3982          A tap changer cannot reach a cim:RegulatingControl.targetValue outside its
3983          capability.
3984          The tap changer upper capability limit (TCUC) in per unit is
3985          - TCUC = 1+cim:RatioTapChanger.stepVoltageIncrement/100*
3986             (cim:TapChanger.highStep-cim:TapChanger.neutralStep)
3987          The tap changer lower capability limit (TCLC) in per unit is
3988          - TCLC = 1-cim:RatioTapChanger.stepVoltageIncrement/100*
3989             (cim:TapChanger.neutralStep-cim:TapChanger.lowStep)
3990          The TCUC and TCLC are in per unit (PU)
3991          The target value in PU is TargetValuePU =
3992          cim:RegulatingControl.targetValue/cim:BaseVoltage.nominalVoltage
3993          where the cim:BaseVoltage is from the controlled Terminal.
3994          The rule is
3995          - min(TCLC,TCUC) GreaterOrEqual TargetValuePU LessOrEqual max(TCLC,TCUC)
3996          Note1: The cim:TapChanger.controlEnabled and
3997          cim:RequlatingControl.enabled flags are to be considered.
3998          Note2: cim:TapChangerControlMode shall be set to voltage control.
3999
4000          Justification:
4001          The transformer cannot meet the requested target value.
4002
4003          Message:
4004          The cim:RegulatingControl.targetValue outside the cim:TapChanger
4005          capability.
4006
4007          Usage: #IGMRuleSet #CGMRuleSet
4008
4009    Rule: IDuniqueness  Level: 5  Severity: ERROR
4010
4011          Details:
```

```
4012          All mRIDs (rdf:ID or rdf:about) in a model shall
4013          be unique.
4014
4015          Justification:
4016          All mRIDs (rdf:ID or rdf:about) shall be globally unique
4017          as stated in IEC 61970-552.
4018          See IEC TS 61970-600-1:2017 GENC1.
4019
4020          Message:
4021          mRID (rdf:ID or rdf:about) not unique within model.
4022
4023          Usage: #IGMRuleSet #CGMRuleSet
4024
4025    Rule: TCCRemoteReactiveFlow  Level: 5  Severity: WARNING
4026
4027          Details:
4028          A cim:TapChangerControl (TCC) controlling reactive power flow should control the
4029    flow at one of the cim:Terminal-s belonging
4030          to cim:PowerTransformerEnd-s in the cim:PowerTransformer where the
4031          cim:TapChanger is located.
4032          Control a remote cim:Terminal (even if it is within the MAS) not belonging to the
4033    cim:PowerTransformer
4034          with the cim:TapChanger is not allowed.
4035          Note: A result of this is that multiple cim:TapChanger-s cannot be
4036          controlled by the same TCC.
4037
4038          Justification:
4039          A power transformer cannot efficiently control reactive power flow
4040          other than on its own terminals.
4041
4042          Message:
4043          A cim:TapChangerControl for reactive power flow is controlling a
4044          cim:Terminal that is not connected to one of the cim:PowerTransformerEnd-s.
4045
4046          Usage: #IGMRuleSet
4047
4048    Rule: SynchronousCondenserMode  Level: 5  Severity: WARNING
4049
4050          Details:
4051          For a synchronous condenser (cim:SynchronousMachine.type = condenser)
4052          there is no capability for real power output.
4053          In this case, the cim:SynchronousMachine.operationMode should be condenser.
4054
4055          Justification:
4056          The name plate ratings are used as a reference.
4057          See IEC TS 61970-600-2:2017, section 6.9.47.
4058
4059          Message:
4060          A synchronous condenser should have cim:SynchronousMachine.operatingMode
4061          set to condenser.
4062
4063          Usage: #IGMRuleSet #CGMRuleSet
4064
```

8 LEVEL 6 VALIDATION: IGM AND CGM PLAUSIBILITY

8.1 INTRODUCTION

In this category, the focus is on identifying modelling assumptions in scenarios that impact convergence behaviour. From experience, the following root causes have been identified:

- Multiple electrical islands in an individual grid model;
- Insufficient voltage control capabilities;
- (Large) negative loads;
- Large reactive power values on PQ nodes;
- Unrealistic voltage target values (outside voltage limits of TSOs);
- Impact of cables not modelled (affects the power factor when performing load scaling);
- Low impedance equipment (short cables or low impedance transformers).

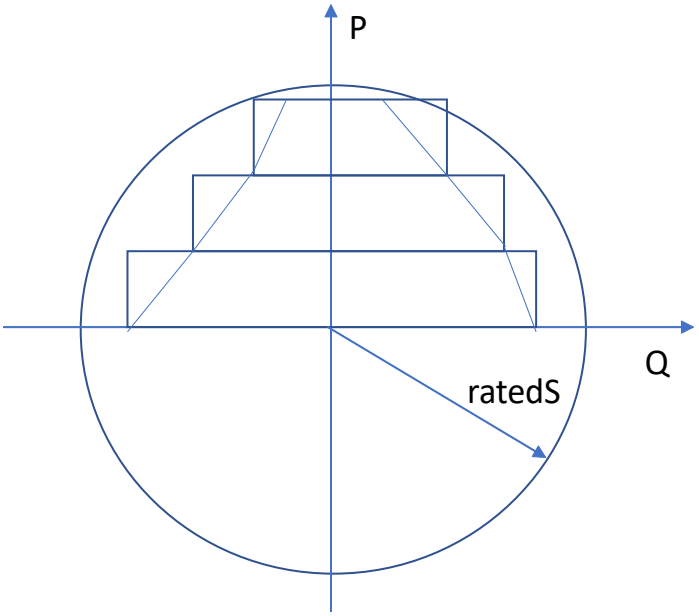
8.2 INDICATORS (AFTER LOAD FLOW CALCULATION)

- Large slack node deviation value (active power).
- Solved state variables far from initial (complex) voltage values.
- Oscillation in voltage deviations during iterations.
- A lot of iterations needed before convergence tolerance is met.
- Multiple synchronous machines are bound (switched to PQ nodes).
- Mathematical solution cannot be found (diverging voltage deviations between iterations).

8.3 INTERPOLATION IN REACTIVE CAPABILITY CURVE

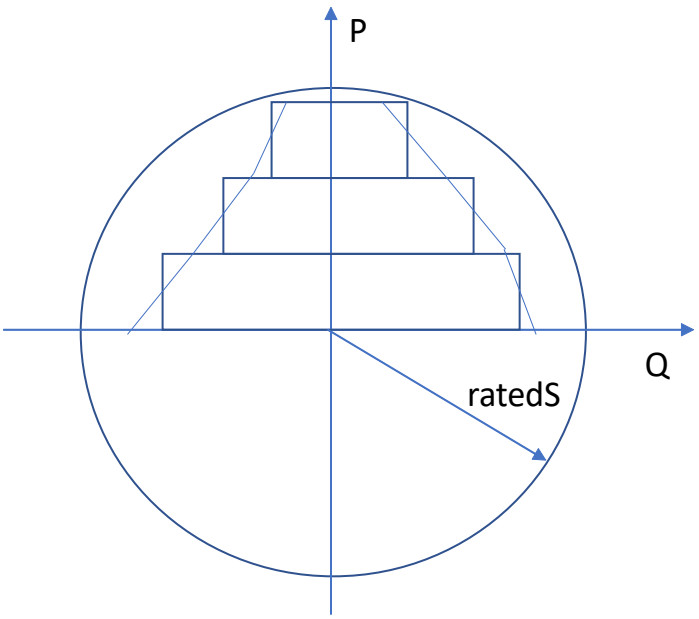
A reactive capability curve typically has at least two curve points. If an interpolation function is not available three possible approximations are possible

1. Min of pairwise negative Q values and max of pairwise positive Q values, see Figure 12
2. Mean value of pairwise Q values, see Figure 13.
3. Max of pairwise negative Q values and min of pairwise positive Q values, see Figure 14.



4092

4093 **Figure 12 Pairwise max Value**



4097

4098 **Figure 13 Pairwise Mean Value**

4099 For this option a reactive power at the limit may stay within the capability curve limit.

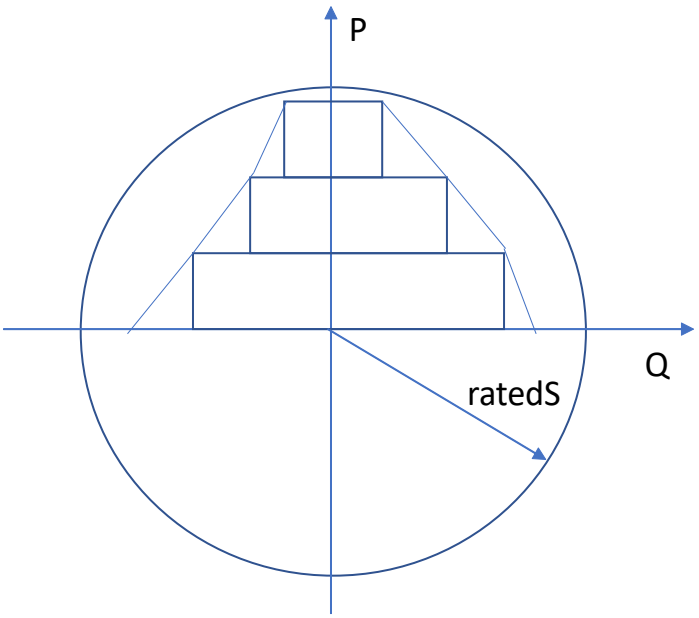


Figure 14 Pairwise Min Value

For this is option a reactive power at the limit will always be inside the reactive capability curve.

8.4 VALIDATION RULES

```
Rule: SCSections  Level: 6  Severity: ERROR

      Details:
      For every instance of cim:ShuntCompensator, cim:LinearShuntCompensator and
      cim:NonLinearShuntCompensator, the value of cim:ShuntCompensator.sections
      should be lower than or equal to the value of
      cim:ShuntCompensator.maximumSections.

      Justification:

      Message:
      Number of sections out of range.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: GenActivePowerInfeedLim  Level: 6  Severity: WARNING

      Details:
      The negated value of cim:RotatingMachine.p shall be within the following range
      depending on the value of cim:SynchronousMachine.operatingMode:
      1) In case of cim:SynchronousMachineOperatingMode.generator
            • [cim:GeneratingUnit.minOperatingP,cim:GeneratingUnit.maxOperatingP]  if
              cim:GeneratingUnit.minOperatingP is greater than or equal to zero.
            • [0,cim:GeneratingUnit.maxOperatingP]                                 if
              cim:GeneratingUnit.minOperatingP is less than zero.
      2) In case of cim:SynchronousMachineOperatingMode.motor
```

- [cim:GeneratingUnit.minOperatingP,cim:GeneratingUnit.maxOperatingP] if cim:GeneratingUnit.minOperatingP is less than zero and cim:GeneratingUnit.maxOperatingP is less than or equal to zero.
- [cim:GeneratingUnit.minOperatingP,0] if cim:GeneratingUnit.maxOperatingP is greater than zero.

3) In case of cim:SynchronousMachineOperatingMode.condenser cim:RotatingMachine.p shall equal to zero as there is no active power output.

Note 1: Negation is necessary due to the load sign convention.
Note 2: A cim:SynchronousMachine with cim:RotatingMachine.p = 0 is considered out of service if cim:SynchronousMachine.operatingMode is either cim:SynchronousMachineOperatingMode.motor or cim:SynchronousMachineOperatingMode.generator.
Note 3: In cases where the operating mode is cim:SynchronousMachineOperatingMode.condenser the synchronous machine might in reality output small amounts of active power. This rule will generate warning that can be assessed. It could then be advised that as such amounts do not have substantial effect on the IGM, condensers shall be modelled with zero active power.

Justification:
Load sign convention is used for the power infeed, whereas nameplate ratings are used for the operating limits.

Message:
Active power output of the cim:SynchronousMachine is out of range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: GenActivePowerInfeedDiffW Level: 6 Severity: WARNING

Details:
For every instance of cim:SynchronousMachine, the value of cim:RotatingMachine.p should not deviate more than SSH_SV_MAX_P_DIFF MW from the value of cim:SvPowerFlow.p for the associated terminal.
Note that disconnected synchronous machines should have zero values in SSH.

Justification:
The SSH data should be based on a solved power flow (CGMM) and as a consequence, the values in SSH (input) and SV (calculation results) should not be far away.

Message:
Assumed generation infeed of cim:SynchronousMachine deviates from calculated generation infeed more than SSH_SV_MAX_P_DIFF.

Usage: #IGMRuleSet #CGMRuleSet

Rule: GenActivePowerInfeedDiffE Level: 6 Severity: ERROR

Details:
The aggregated sum of the values of cim:RotatingMachine.p shall not deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of cim:SvPowerFlow.p for the terminals connected to synchronous machines.
Note that disconnected synchronous machines should have zero values in SSH.

Justification:
The SSH data should be based on a solved power flow (CGMM) and as a consequence,

```
4187        the values in SSH (input) and SV (calculation results) should not be far away.
4188
4189        Message:
4190        Assumed aggregated active power generation infeed deviates from calculated
4191        generation infeed more than SSH_SV_TOT_P_DIFF MW.
4192
4193        Usage: #IGMRuleSet #CGMRuleSet
4194
4195    Rule: GenReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4196
4197        Details:
4198        For every instance of cim:SynchronousMachine, the value of
4199        cim:RotatingMachine.q should not deviate more than SSH_SV_MAX_Q_DIFF MVAr
4200        from the value of cim:SvPowerFlow.q for the associated terminal.
4201        Note that disconnected synchronous machines should have zero values in SSH.
4202
4203        Justification:
4204        Considering the Power Flow settings, the reactive power shift
4205        should be minimal.
4206
4207        Message:
4208        Potential reactive power problem located for cim:SynchronousMachine, assumed
4209        reactive power generation of cim:SynchronousMachine deviates from calculated
4210        more than SSH_SV_MAX_Q_DIFF MVAr.
4211
4212        Usage: #IGMRuleSet #CGMRuleSet
4213
4214    Rule: GenReactivePowerInfeedLim  Level: 6  Severity: WARNING
4215
4216        Details:
4217        The reactive power provided to the network by a cim:SynchronousMachine shall
4218        stay within limits regardless if it is controlling or not
4219        - negated cim:RotatingMachine.q greater or equal than cim:SynchronousMachine.minQ
4220           if provided
4221        - negated cim:RotatingMachine.q less or equal than cim:SynchronousMachine.maxQ
4222           if provided
4223        Note1: cim:RotatingMachine.q shall be negated due to the load sign convention.
4224
4225
4226        Justification:
4227        The reactive power infeed at PQ nodes should be within limits.
4228
4229        Message:
4230        Generation reactive power infeed out of range.
4231
4232        Usage: #IGMRuleSet #CGMRuleSet
4233
4234    Rule: GenRCCPowerInfeed  Level: 6  Severity: WARNING
4235
4236        Details:
4237        The power provided to the network by a cim:SynchronousMachine should stay
4238        within limits regardless if it is controlling or not. This rule applies
4239        when a reactive capability curve is present. Active power is restricted as
4240        - RCCCD = RCC.mRID=CD[CD.Curve]
4241        - -RM.p LE max(RCCCD/CD.xvalue) and
4242        - -RM.p GE min(RCCCD/CD.xvalue)
```

```
4243          where
4244          - The notation above is an XPath expression
4245          - RCC = cim:ReactiveCapabilityCurve
4246          - RCCD = The cim:CurveData points that belongs to the RCC
4247          - CD = cim:CurveData
4248          - RM = cim:RotatingMachine, note this is load sign convention
4249          - LE = Less or Equal
4250          - GE = Greater or Equal
4251          Reactive power is restricted as
4252          - CD1 = min(RCCD[CD.xvalue LE -RM.p])
4253          - CD2 = min(RCCD[CD.xvalue GE -RM.p])
4254          - RM.q LE interpolate(CD2/CD.y2value, CD2/CD.xvalue, CD1/CD.y2value,
4255                CD1/CD.xvalue, -RM.p)
4256          - RM.q GE interpolate(CD2/CD.y1value, CD2/CD.xvalue, CD1/CD.y1value,
4257                CD1/CD.xvalue, -RM.p)
4258          where
4259          - CD1 = nearest lower active power limit point
4260          - CD2 = nearest higher active power limit point
4261          - interpolate(w1, z1, w2, z2, w) is a function with parameters
4262             - w1 and z1 = the first coordinate point
4263             - w2 and z2 = the second coordinate point
4264             - w = the value along the w axis to interpolate the value along
4265                the z axis
4266             In case interpolation is not used, the mean value between w1
4267             and w2 should be used as limit.
4268
4269          Justification:
4270          The active and reactive power infeed at PQ nodes should be within limits.
4271
4272          Message:
4273          Generation reactive power infeed out of range.
4274
4275          Usage: #IGMRuleSet #CGMRuleSet
4276
4277    Rule: ValidDER  Level: 6  Severity: WARNING
4278
4279          Details:
4280          For every instance of a DistributedEnergyResource (DER), e.g.
4281          cim:EnergySource, the value of cim:EnergySource.activePower
4282          should be lower than or equal to zero.
4283
4284          Justification:
4285          Due to the load sign convention, decentralized infeed must be
4286          negative or zero.
4287          See IEC TS 61970-600-2:2017 section 7.8.6.
4288
4289          Message:
4290          DER infeed acts as a load.
4291
4292          Usage: #IGMRuleSet #CGMRuleSet
4293
4294    Rule: DERActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4295
4296          Details:
4297          For every instance of cim:EnergySource, the value of
4298          cim:EnergySource.activePower should not deviate more than SSH_SV_MAX_P_DIFF MW
```

```
4299          from the value of cim:SvPowerFlow.p for the associated terminal.
4300          Note that disconnected DER should have zero values in SSH.
4301
4302          Justification:
4303          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4304          the values in SSH (input) and SV (calculation results) should not be far away.
4305
4306          Message:
4307          Assumed generation infeed of cim:EnergySource deviates from calculated generation
4308          infeed more than SSH_SV_MAX_P_DIFF MW.
4309
4310          Usage: #IGMRuleSet #CGMRuleSet
4311
4312    Rule: DERActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4313
4314          Details:
4315          The aggregated sum of the values of cim:EnergySource.activePower shall not
4316          deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of
4317          cim:SvPowerFlow.p for the terminals connected to cim:EnergySource.
4318          Note that disconnected DER should have zero values in SSH.
4319
4320          Justification:
4321          The SSH data should
4322          be based on a solved power flow (CGMM) and as a consequence, the values in
4323          SSH (input) and SV (calculation results) should not be far away.
4324
4325          Message:
4326          Assumed aggregated active power generation infeed deviates from calculated
4327          generation infeed more than SSH_SV_TOT_P_DIFF MW.
4328
4329          Usage: #IGMRuleSet #CGMRuleSet
4330
4331    Rule: DERReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4332
4333          Details:
4334          For every instance of cim:EnergySource, the value of
4335          cim:EnergySource.reactivePower should not deviate more than SSH_SV_MAX_Q_DIFF MVAr
4336          from the value of cim:SvPowerFlow.q for the associated terminal.
4337          Note that disconnected DER should have zero values in SSH.
4338
4339          Justification:
4340          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4341          the values in SSH (input) and SV (calculation results) should not be far away.
4342
4343          Message:
4344          Assumed generation infeed of cim:EnergySource deviates from calculated generation
4345          infeed more than SSH_SV_MAX_Q_DIFF MVAr.
4346
4347          Usage: #IGMRuleSet #CGMRuleSet
4348
4349    Rule: ValidLoad  Level: 6  Severity: WARNING
4350
4351          Details:
4352          For every instance of cim:StationSupply, cim:ConformLoad and
4353          cim:NonConformLoad, the value of cim:EnergyConsumer.p should be greater
4354          than or equal to zero.
```

```
4355
4356          Justification:
4357          Due to the load sign convention, all loads should be
4358          positive or zero. Decentralized generation should be modelled explicitly.
4359          See IEC TS 61970-600-2:2017 section 7.8.5.
4360
4361          Message:
4362          Load infeed acts as a generator.
4363
4364          Usage: #IGMRuleSet #CGMRuleSet
4365
4366    Rule: LoadActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4367
4368          Details:
4369          For every instance of cim:StationSupply, cim:ConformLoad and
4370          cim:NonConformLoad, the value of cim:EnergyConsumer.p should not deviate
4371          more than SSH_SV_MAX_P_DIFF MW from the value of cim:SvPowerFlow.p for the
4372          associated terminal. Note that disconnected loads should have zero values in SSH.
4373
4374          Justification:
4375          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4376          the values in SSH (input) and SV (calculation results) should not be far away.
4377
4378          Message:
4379          Assumed consumption deviates from calculated consumption more than
4380          SSH_SV_MAX_P_DIFF MW.
4381
4382          Usage: #IGMRuleSet #CGMRuleSet
4383
4384    Rule: LoadActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4385
4386          Details:
4387          The aggregated sum of the values of cim:EnergyConsumer.p shall not
4388          deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the values of
4389          cim:SvPowerFlow.p for the associated terminals. Note that disconnected
4390          loads should have zero values in SSH.
4391
4392          Justification:
4393          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4394          the values in SSH (input) and SV (calculation results) should not be far away.
4395
4396          Message:
4397          Assumed aggregated consumption deviates from calculated consumption
4398          more than SSH_SV_TOT_P_DIFF MW.
4399
4400          Usage: #IGMRuleSet #CGMRuleSet
4401
4402    Rule: LoadReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4403
4404          Details:
4405          For every instance of cim:StationSupply, cim:ConformLoad and
4406          cim:NonConformLoad, the value of cim:EnergyConsumer.q should not deviate
4407          more than SSH_SV_MAX_Q_DIFF MVAr from the value of cim:SvPowerFlow.q for the
4408          associated terminal. Note that disconnected loads should have zero values in SSH.
4409
4410          Justification:
```

```
4411        Considering the Power Flow settings, the reactive power shift
4412        should be minimal.
4413
4414        Message:
4415        Potential reactive power problem located for load instance, assumed reactive power
4416        deviates from calculated more than SSH_SV_MAX_Q_DIFF MVAr.
4417
4418        Usage: #IGMRuleSet #CGMRuleSet
4419
4420  Rule: ENIActivePowerInfeedLim  Level: 6  Severity: WARNING  Template: RuleModel
4421        Details:
4422        The negated value of cim:ExternalNetworkInjection.p should be within the range
4423  [cim:ExternalNetworkInjection.minP, cim:ExternalNetworkInjection.maxP]. The validation
4424  takes into account that both cim:ExternalNetworkInjection.minP and
4425  cim:ExternalNetworkInjection.maxP will be negative if the equivalent injection is
4426  representing load operating range as cim:ExternalNetworkInjection.minP and
4427  cim:ExternalNetworkInjection.maxP are following generator sign convention (i.e. positive
4428  sign when generating power).
4429        Note1: Negation is necessary due to the load sign convention.
4430        Note2: An instance with cim:ExternalNetworkInjection.p = 0
4431        is considered out of service.
4432
4433        Justification:
4434        Load sign convention is used for the power infeed. The operating point should be
4435  within defined limits.
4436
4437        Message:
4438        ExternalNetworkInjection active power infeed is out of range.
4439
4440        Usage: #IGMRuleSet #CGMRuleSet
4441
4442  Rule: ENIReactivePowerInfeedLim  Level: 6  Severity: WARNING
4443
4444        Details:
4445        The negated value of cim:ExternalNetworkInjection.q should be within the range
4446  [cim:ExternalNetworkInjection.minQ, cim:ExternalNetworkInjection.maxQ]. The validation
4447  takes into account that both cim:ExternalNetworkInjection.minQ and
4448  cim:ExternalNetworkInjection.maxQ will be negative if the equivalent injection is
4449  representing load operating range as cim:ExternalNetworkInjection.minQ and
4450  cim:ExternalNetworkInjection.maxQ are following generator sign convention (i.e. positive
4451  sign when generating power).
4452        Note1: Negation is necessary due to the load sign convention.
4453
4454        Justification:
4455        Load sign convention is used for the power infeed. The operating point should be
4456  within defined limits.
4457
4458        Message:
4459        ExternalNetworkInjection reactive power infeed is out of range.
4460
4461        Usage: #IGMRuleSet #CGMRuleSet
4462
4463  Rule: ENIActivePowerInfeedDiffW  Level: 6  Severity: WARNING
4464
4465        Details:
4466        For every instance of cim:ExternalNetworkInjection, the value of
```

```
4467          cim:ExternalNetworkInjection.p should not deviate more than SSH_SV_MAX_P_DIFF MW
4468          from the value of cim:SvPowerFlow.p for the associated terminal
4469
4470          Justification:
4471          The SSH data should be based on a solved power flow (CGMM)
4472          and as a consequence, the values in SSH (input) and SV (calculation results)
4473          should not be far away.
4474          Note: cim:ExternalNetworkInjection should not be used frequently considering its
4475          purpose.
4476
4477          Message:
4478          Assumed external injection deviates from calculated
4479          more than SSH_SV_MAX_P_DIFF MW.
4480
4481          Usage: #IGMRuleSet #CGMRuleSet
4482
4483    Rule: ENIActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4484
4485          Details:
4486          The aggregated sum of the values of cim:ExternalNetworkInjection.p shall
4487          not deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of the
4488          values of cim:SvPowerFlow.p for the associated terminals
4489
4490          Justification:
4491          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4492          the values in SSH (input) and SV (calculation results) should not be far away.
4493          Note: cim:ExternalNetworkInjection should not be used frequently considering its
4494          purpose.
4495
4496          Message:
4497          Assumed aggregated sum of external injections deviates from calculated
4498          more than SSH_SV_TOT_P_DIFF MW
4499
4500          Usage: #IGMRuleSet #CGMRuleSet
4501
4502    Rule: ENIReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4503
4504          Details:
4505          For every cim:ExternalNetworkInjection the value of
4506          cim:ExternalNetworkInjection.q should not deviate
4507          more than SSH_SV_MAX_Q_DIFF MVAr from the value of cim:SvPowerFlow.q for the
4508          associated terminal.
4509          Note that disconnected loads should have zero values in SSH.
4510
4511          Justification:
4512          Considering the Power Flow settings, the reactive power shift
4513          should be minimal.
4514
4515          Message:
4516          Potential reactive power problem located for cim:ExternalNetworkInjection,
4517          assumed reactive power deviates from calculated more than
4518          SSH_SV_MAX_Q_DIFF MVAr
4519
4520          Usage: #IGMRuleSet #CGMRuleSet
4521
4522    Rule: EIActivePowerInfeedLim  Level: 6  Severity: WARNING
```

Details:
The negated value of non-boundary cim:EquivalentInjection.p should be within the range [cim:EquivalentInjection.minP, cim:EquivalentInjection.maxP]. The validation takes into account that both cim:EquivalentInjection.maxP and cim:EquivalentInjection.minP will be negative if the equivalent injection is representing load operating range as cim:EquivalentInjection.minP and cim:EquivalentInjection.maxP are following generator sign convention (i.e. positive sign when generating power).
Note1: Negation is necessary due to the load sign convention.
Note2: An instance with cim:EquivalentInjection.p = 0 is considered out of service.

Justification:
Load sign convention is used for the power infeed. The operating point should be within defined limits.

Message:
EquivalentInjection active power infeed is out of range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: EIReactivePowerInfeedLim Level: 6 Severity: WARNING

Details:
The negated value of non-boundary cim:EquivalentInjection.q should be with the range [cim:EquivalentInjection.minQ, cim:EquivalentInjection.maxQ]. The validation takes into account that both cim:EquivalentInjection.maxQ and cim:EquivalentInjection.minQ will be negative if the equivalent injection is representing load operating range as cim:EquivalentInjection.minQ and cim:EquivalentInjection.maxQ are following generator sign convention (i.e. positive sign when generating power).
Note1: Negation is necessary due to the load sign convention.

Justification:
Load sign convention is used for the power infeed. The operating point should be within defined limits.

Message:
EquivalentInjection reactive power infeed is out of range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: EIActivePowerInfeedDiffW Level: 6 Severity: WARNING

Details:
For every non-boundary cim:EquivalentInjection, the value of
cim:EquivalentInjection.p should not deviate more than SSH_SV_MAX_P_DIFF MW
from the value of cim:SvPowerFlow.p for the associated terminal

Justification:
The SSH data should be based on a solved power flow (CGMM) and as a consequence, the values in SSH (input) and SV (calculation results) should not be far away.
Note: cim:EquivalentInjection should not be used frequently considering its purpose.

Message:
Assumed non-boundary cim:EquivalentInjection injection deviates from calculated more than SSH_SV_MAX_P_DIFF MW.

```
4579
4580          Usage: #IGMRuleSet #CGMRuleSet
4581
4582    Rule: EIActivePowerInfeedDiffE  Level: 6  Severity: ERROR
4583
4584          Details:
4585          The aggregated sum of the values of non-boundary cim:EquivalentInjection.p
4586          shall not deviate more than SSH_SV_TOT_P_DIFF MW from the aggregated sum of
4587          the values of cim:SvPowerFlow.p for the associated terminals
4588
4589          Justification:
4590          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4591          the values in SSH (input) and SV (calculation results) should not be far away.
4592          Note: cim:EquivalentInjection should not be used frequently considering its
4593          purpose.
4594
4595          Message:
4596          Assumed non-boundary cim:EquivalentInjection aggregated injection deviates from
4597          calculated more than SSH_SV_TOT_P_DIFF MW.
4598
4599          Usage: #IGMRuleSet #CGMRuleSet
4600
4601    Rule: EIReactivePowerInfeedDiffW  Level: 6  Severity: WARNING
4602
4603          Details:
4604          For every instance of cim:EquivalentInjection, the value of
4605          cim:EquivalentInjection.q should not deviate more than SSH_SV_MAX_Q_DIFF Mvar
4606          from the value of cim:SvPowerFlow.q for the associated terminal.
4607
4608
4609          Justification:
4610          The SSH data should be based on a solved power flow (CGMM) and as a consequence,
4611          the values in SSH (input) and SV (calculation results) should not be far away.
4612
4613          Message:
4614          Assumed generation infeed of cim:EquivalentInjection deviates from calculated
4615    generation
4616          infeed more than SSH_SV_MAX_Q_DIFF Mvar.
4617
4618          Usage: #IGMRuleSet #CGMRuleSet
4619
4620
4621    Rule: NetInterchange1  Level: 6  Severity: WARNING
4622
4623          Details:
4624          For a cim:ControlArea of type interchange the aggregated sum of the values
4625          of cim:SvPowerFlow.p for cim:Terminals referenced by cim:TieFlow.Terminal shall
4626          not deviate from the value of cim:ControlArea.netInterchange with more than
4627          cim:ControlArea.pTolerance, if provided. In cases where cim:ControlArea.pTolerance
4628    is not provided the value of INTERCH_IMBALANCE_WARNING MW is used in the comparison.
4629
4630          There are some implications from other rules to be considered:
4631       1) According to level 5 rule SvPowerFlowBranchInstances the cim:Terminal referenced
4632          by a cim:TieFlow.Terminal is located at a boundary
4633          cim:TopologicalNode, hence the attribute cim:TieFlow.positiveFlowIn
4634          is always true.
```

2) According to level 5 rule SvPowerFlowBranchInstances2 the cim:Terminal of cim:ACLineSegment, cim:PowerTransformer or cim:Switch, etc. should have a cim:SvPowerFlow.
3) According to level 5 rule SvPowerFlowInstances every cim:EquivalentInjection has a cim:SvPowerFlow.

As a consequence cim:SvPowerFlow related to boundary cim:EquivalentInjection-s must be used in the summation but with negated value. cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of cim:EquivalentInjection, which is connected to a boundary cim:TopologicalNode, referenced by a cim:Terminal, which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.

Note1: cim:ControlArea.netInterchange include AC and DC exchanges.
Note2: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description attribute with leading characters 'HVDC'.

Justification:
Area interchange control uses ControlArea.netInterchange as set point, the TieFlow terminals as State Variables and the ConformLoad within the ControlArea as Control Variables.

Message:
Netted Area position not respected more than INTERCH_IMBALANCE_WARNING MW or cim:ControlArea.pTolerance, if provided.

Usage: #IGMRuleSet #CGMRuleSet

Rule: NetInterchange2 Level: 6 Severity: ERROR

Details:
For a cim:ControlArea of type interchange the aggregated sum of the values of cim:SvPowerFlow.p for cim:Terminals referenced by cim:TieFlow.Terminal shall not deviate from the value of cim:ControlArea.netInterchange with more than INTERCH_IMBALANCE_ERROR MW.
There are some implications from other rules to be considered:
1) According to level 5 rule SvPowerFlowBranchInstances the cim:Terminal referenced by a cim:TieFlow.Terminal is located at a boundary cim:TopologicalNode, hence the attribute cim:TieFlow.positiveFlowIn is always true.
2) According to level 5 rule SvPowerFlowBranchInstances2 the cim:Terminal of cim:ACLineSegment, cim:PowerTransformer or cim:Switch, etc. should have a cim:SvPowerFlow.
3) According to level 5 rule SvPowerFlowInstances every cim:EquivalentInjection has a cim:SvPowerFlow.

As a consequence cim:SvPowerFlow related to boundary cim:EquivalentInjection-scim:Terminal must be used in the summation but with negated value.
cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of cim:EquivalentInjection, which is connected to a boundary cim:TopologicalNode, referenced by a cim:Terminal, which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
Note1: cim:ControlArea.netInterchange include AC and DC exchanges.
Note2: An HVDC Boundary TopologicalNode has a cim:IdentifiedObject.description attribute with leading characters 'HVDC'.

Justification:
Area interchange control uses ControlArea.netInterchange as

set point, the TieFlow terminals as State Variables and the ConformLoad within the ControlArea as Control Variables.

Message:
Netted Area position severely not respected for more than INTERCH_IMBALANCE_ERROR MW.

Usage: #IGMRuleSet #CGMRuleSet

Rule: TapPosition Level: 6 Severity: WARNING

Details:
For every instance of cim:RatioTapChanger, cim:PhaseTapChangerLinear, cim:PhaseTapChangerSymmetrical and cim:PhaseTapChangerAsymmetrical, which has cim:RegulatingControl.enabled equal to true, the value of cim:TapChanger.step should not deviate more than SSH_SV_MAX_TAP_STEP_DIFF from the value of cim:SvTapStep.position.

Justification:
Considering the Power Flow settings, the tap position shift should be minimal. The SSH data should be based on a solved power flow (CGMM) and as a consequence, the values in SSH (input) and SV (calculation results) should not be far away.

Message:
Initial tap position deviates more than SSH_SV_MAX_TAP_STEP_DIFF from calculated.

Usage: #IGMRuleSet #CGMRuleSet

Rule: ShuntQ Level: 6 Severity: WARNING

Details:
The rule is checking if cim:SvPowerFlow.q of a cim:LinearShuntCompensator is consistent with cim:SvShuntCompensatorSections.sections. Therefore, for every instance of cim:LinearShuntCompensator, which has cim:RegulatingControl.enabled equals true, the value of cim:SvPowerFlow.q should not deviate more than SSH_SV_MAX_Q_SHUNT_DIFF MVAr from the negated product of the value of cim:SvShuntCompensatorSections.sections, the value of cim:LinearShuntCompensator.bPerSection and the squared value of cim:SvVoltage.v at the cim:TopologicalNode where the cim:LinearShuntCompensator is connected to.

Justification:

Message:
Calculated reactive power output of cim:LinearShuntCompensator differs from cim:SvPowerFlow.q of a cim:LinearShuntCompensator with more than SSH_SV_MAX_Q_SHUNT_DIFF Mvar.

Usage: #IGMRuleSet #CGMRuleSet

Rule: SvInjectionLimit Level: 6 Severity: WARNING

Details:
The absolute value of cim:SvInjection.pInjection shall be less than the SV_INJECTION_LIMIT MW.

The absolute value of cim:SvInjection.qInjection shall be less than the SV_INJECTION_LIMIT Mvar.
cim:SvInjection is instantiated only if P and Q tolerances defined in the power flow calculation settings are not met.

Justification:
The cim:SvInjection values gives the accuracy of the power flow solution.
Large values of cim:SvInjection.pInjection and cim:SvInjection.qInjection
indicates a poorly converged power flow solution.
Lots of cim:SvInjection instances below limit will clutter the SV file.

Message:
cim:SvInjection which has either pInjection or qInjection greater than
SV_INJECTION_LIMIT.

Usage: #IGMRuleSet #CGMRuleSet

Rule: VoltageProfile Level: 6 Severity: WARNING

Details:
Where a cim:VoltageLimit exists for an energized cim:TopologicalNode,
the value of cim:SvVoltage.v
should be lower than or equal to the value of cim:VoltageLimit.value
associated with cim:OperationalLimitType.limitType=highVoltage and higher
than or equal to the value of cim:VoltageLimit.value associated with
cim:OperationalLimitType.limitType=lowVoltage.
In case of multiple limits, the most restrictive shall be used.

Justification:
Considering the Power Flow settings, all voltages should be
within defined operational limits.
See IEC TS 61970-600-2:2017 section 6.8.7.

Message:
Calculated voltage out of range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: VoltageTargetsAtTN Level: 6 Severity: WARNING

Details:
For all cim:RegulatingControl instances, with cim:RegulatingControl.discrete=false
(including its subclass cim:TapchangerControl)
regulating the same cim:TopologicalNode their cim:RegulatingControl.targetValues
should be equal. This rule is for continuous controls, for which RegulatingControl.mode equals RegulatingControlModeKind.voltage and RegulatingControl.enabled equals true.

Justification:
The power flow solver need a single voltage target per cim:TopologicalNode
and the cim:RegulatingControl.targetValues differ the power flow will
have to pick a value. If different Power Flow applications use different
strategies to pick a value the voltage
solution will differ between them which is the reason to warn.

Message:
Conflicting target values of cim:RegulatingControl regulating voltage at the same cim:TopologicalNode.

Usage: #IGMRuleSet #CGMRuleSet

Rule: VoltageTargetAndDeadbandAtTN Level: 6 Severity: WARNING

Details:
For all cim:RegulatingControl (including its subclass cim:TapChangerControl) instances at a cim:TopologicalNode with one or more cim:RegulatingControls that have:
- cim:RegulatingControl.discrete set to true
- cim:RegulatingControl.enabled set to true, and
- cim:RegulatingControl.mode set to cim:RegulatingControlModeKind.voltage,
shall have cim:RegulatingControl.targetValue within the intersection of regulating ranges formed by all discrete cim:RegulatingControl regulating a cim:TopologicalNode.
The range for a discrete control (cim:RegulatingControl.discrete set to true) is {cim:RegulatingControl.targetValue - cim:RegulatingControl.targetDeadband/2, cim:RegulatingControl.targetValue + cim:RegulatingControl.targetDeadband/2}

Note: the rule is validating both if the ranges of discrete regulating control form intersection and if the target values of all regulating controls are within the intersection regulating range.

Justification:
The power flow solver need a single deadband per cim:TopologicalNode and if the deadbands differ the power flow will have to pick a value. If different Power Flow applications use different strategies to pick a value the voltage solution will differ between them which is the reason to warn.

Message:
Either 1) Regulating ranges of discrete regulating controls do not create intersection or 2) the target values of regulating controls are not within the intersection range.

Usage: #IGMRuleSet #CGMRuleSet

Rule: EnergizedBoundaryTN Level: 6 Severity: ERROR

Details:
A boundary cim:TopologicalNode with a non-zero cim:EquivalentInjection.p or cim:EquivalentInjection.q is supposed to be energized and shall have a solved voltage, i.e. cim:SvVoltage.v shall not be zero.

Justification:
All boundary cim:TopologicalNodes in a power flow model shall have a solved voltage.

Message:
Boundary cim:TopologicalNode with injecting cim:EquivalentInjection without solved cim:SvVoltage.v.

Usage: #IGMRuleSet #CGMRuleSet

```
Rule: FakeVoltage  Level: 6  Severity: WARNING

      Details:
      A cim:TopologicalNode with a solved voltage equal to the
      cim:BaseVoltage.nominalVoltage is suspected to copy that value rather than
      solving to power flow.

      Justification:
      This is to prevent from faking the voltage.

      Message:
      Voltage at cim:TopologicalNode may be fake.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: InvalidVoltage  Level: 6  Severity: ERROR

      Details:
      A cim:SvVoltage lower than 0.4 per unit and greater than 0 is not allowed.

      Justification:
      A cim:SvVoltage lower than 0.4 per unit and greater than 0 is not reasonable.

      Message:
      A cim:SvVoltage lower than 0.4 per unit and greater than 0 is not allowed.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: DiscreteControl  Level: 6  Severity: ERROR

      Details:
      For every instance of cim:RegulatingControl (SSH) for which the value of
      cim:RegulatingControl.discrete is true and cim:RegulatingControl.enabled
      is true the control variables must move in discrete steps. Hence no decimals
      are allowed for the following attributes values:
      - cim:ShuntCompensator.sections
      - related cim:SvShuntCompensatorSections.sections
      - cim:TapChanger.step
      - related cim:SvTapStep.position.

      Justification:
      If cim:RegulatingControl.discrete is set to true it is not possible
      to move the control variables continuously.

      Message:
      cim:ShuntCompensator.sections or cim:TapChanger.step or
      SvShuntCompensatorSection.sections or SvTapStep.position
      shall be an integer value in discrete control.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: ContinuousControl  Level: 6  Severity: WARNING

      Details:
      For every instance of cim:RegulatingControl (SSH) for which the value of
      cim:RegulatingControl.discrete is false and cim:RegulatingControl.enabled
```

```
4915        is true means continuous control. For devices natively being discrete this
4916        means an imprecise modelling of the behaviour for
4917        - cim:ShuntCompensator
4918        - cim:TapChanger.
4919
4920        Justification:
4921        If cim:RegulatingControl.discrete is false continuous control is used
4922        which is an imprecise model.
4923        For as built equipment the most precise model should be used.
4924
4925        Message:
4926        cim:ShuntCompensator or cim:TapChanger should not be used with continuous control.
4927
4928        Usage: #IGMRuleSet #CGMRuleSet
4929
4930   Rule: RequiredSvVoltage  Level: 6  Severity: ERROR
4931
4932        Details:
4933        Instances of cim:SvVoltage is required for all cim:TopologicalNodes.
4934        If power flow didn't create a solution for a cim:TopologicalNode
4935        cim:SvVoltage angle and voltage shall be set to zero.
4936
4937        Justification:
4938        Instances of cim:SvVoltage is required to know where power flow managed
4939        to solve.
4940
4941        Message:
4942        cim:SvVoltage is missing for cim:TopologicalNode.
4943
4944        Usage: #IGMRuleSet #CGMRuleSet
4945
4946   Rule: RequiredSvSCSections  Level: 6  Severity: ERROR
4947
4948        Details:
4949        The following shall be satisfied for cim:ShuntCompensator:
4950        1) Each instance of cim:ShuntCompensator shall have cim:SvShuntCompensatorSections
4951           instantiated.
4952        2) For a cim:ShuntCompensator that is not used in control by power flow (no
4953           cim:RegulatingControl associated or if cim:RegulatingControl.enabled equals
4954           false) the value of SvShuntCompensatorSections.sections shall be the same as
4955           cim:ShuntCompensator.sections.
4956
4957        Justification:
4958        Instances of cim:SvShuntCompensatorSections is required to tell the number
4959        of sections that was used in the solution.
4960
4961        Message:
4962        cim:SvShuntCompensatorSections is missing for shunt compensator or the
4963        cim:SvShuntCompensatorSections.sections is not the same as
4964        cim:ShuntCompensator.sections.
4965
4966        Usage: #IGMRuleSet #CGMRuleSet
4967
4968   Rule: RequiredSvTapStep  Level: 6  Severity: ERROR
4969
4970        Details:
```

For a cim:TapChanger that is not used in control (no cim:TapChangerControl associated or if cim:RegulatingControl.enabled equals false) by power flow the value of SvTapStep.step shall be the same as cim:TapChanger.step.

Justification:
Instances of cim:SvTapStep is required to tell the step number that was used in the solution.

Message:
cim:SvTapStep.step is not the same as cim:TapChanger.step.

Usage: #IGMRuleSet #CGMRuleSet

9 LEVEL 7 VALIDATION: COORDINATION

9.1 INTRODUCTION

In this category, we validate IGMs against other IGMs and against reference data. This can only be done when neighbouring TSO issued their IGMs for the same scenarioTime and if reference data from PEVF or CGMA is available for the same scenarioTime. The referenced MAS always applies to IGM the referenced Power System Resources belong to.

9.2 VALIDATION RULES

Rule: InconsistentCurrentLimits Level: 7 Severity: WARNING

Details:
The value of cim:CurrentLimit.value is expected to be the same for a tie line on both sides of the boundary point.
The rule applies only for cim:CurrentLimit which has association end cim:OperatingLimit.OperatingLimitType referencing a cim:OperatingLimitType with entsoe: OperatingLimitType.limitType equal to entsoe:LimitTTypeKind.patl.
The lowest limit shall be used in studies.

Justification:
Tie line data is supposed to be coordinated by TSOs.

Message:
Current limits of type PATL are inconsistent at a tie line.

Usage: #CGMRuleSet

Rule: UnpairedTieFlow Level: 7 Severity: WARNING

Details:
The rule is checking SSH values only.
A boundary cim:TopologicalNode (AC) in a CGM may be connected to
1) two branches and two cim:EquivalentInjections linking two IGMs
2) one branch and one cim:EquivalentInjection terminating the IGM.

```
5017        In case 1) the cim:EquivalentInjections shall have p/q values
5018        equal zero (no transfer of power) or different from zero (transfer
5019        of power). Having zero values on one side and non-zero on the other
5020        indicates different assumptions on usage of the tie line.
5021        In case 2) the cim:EquivalentInjection p and q values are injections
5022        representing the tie line power flow.
5023        Note: An HVDC Boundary Point has a cim:IdentifiedObject.description
5024        attribute with leading characters equal to 'HVDC'.
5025
5026        Justification:
5027        cim:TieFlow is typically calculated at the AC Tie Line terminal,
5028        connected to the boundary point for AC Tie Lines (regardless of its
5029        position on the Tie line) and at the Point of Common Coupling for HVDC
5030        links
5031
5032        Message:
5033        Tie lines at the boundary have different operational conditions.
5034
5035        Usage: #CGMRuleSet
5036
5037  Rule: ACTielineBV  Level: 7  Severity: ERROR
5038
5039        Details:
5040        For a cim:ControlArea of type interchange all cim:TieFlow branches, which:
5041        -   are not connected to an HVDC boundary point, and
5042        -   have a direct association to cim:BaseVoltage
5043        shall have a cim:BaseVoltage.nominalVoltage that deviates no more than
5044        BOUNDARY_BV_MAX_DIFF from the cim:BaseVoltage.nominalVoltage of the
5045        boundary point obtained from the association end cim:TopologicalNode.BaseVoltage.
5046        Note: An HVDC Boundary Point has a cim:IdentifiedObject.description
5047        attribute equal to 'HVDC'.
5048
5049        Justification:
5050        See section 6.10.2 of IEC TS 61970-600-2:2017.
5051
5052        Message:
5053        AC Tie line nominalVoltage deviates from the boundary point base voltage
5054        more than BOUNDARY_BV_MAX_DIFF.
5055
5056        Usage: #IGMRuleSet #CGMRuleSet
5057
5058  Rule: ACScheduleMatch1  Level: 7  Severity: WARNING
5059
5060        Details:
5061        The sum of cim:SvPowerFlow.p should match
5062        the value of the external AC schedule with the same cim:ControlArea EIC 'Y'
5063        code within INTERCH_IMBALANCE_WARNING MW threshold. The following conditions apply
5064  when creating the sum:
5065        -   cim:SvPowerFlow related to boundary cim:EquivalentInjection-s must be used in
5066            the summation but with negated value.
5067        -   cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
5068            cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5069            (HVDC Boundary TopologicalNode-s are excluded), referenced by a cim:Terminal,
5070            which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
5071
5072        Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description
```

```
5073          attribute with leading characters 'HVDC'.
5074
5075          Justification:
5076          In the Reporting Information Market Document, issued by PEVF or CGMA,
5077          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5078          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the ControlArea
5079          instance.
5080
5081          Message:
5082          AC tie flows doesn't match the scheduled interchange value
5083          more than INTERCH_IMBALANCE_WARNING MW.
5084
5085          Usage: #IGMRuleSet #CGMRuleSet
5086
5087    Rule: ACScheduleMatch2  Level: 7  Severity: ERROR
5088
5089          Details:
5090          The sum of cim:SvPowerFlow.p tie flows should match
5091          the value of the external AC schedule with the same cim:ControlArea
5092          EIC 'Y' code within INTERCH_IMBALANCE_ERROR MW threshold.
5093          The following conditions apply when creating the sum:
5094          -   cim:SvPowerFlow related to boundary cim:EquivalentInjection-s must be used in
5095              the summation but with negated value.
5096          -   cim:SvPowerFlow participates in the sum if the cim:Terminal is a terminal of
5097              cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode
5098              (HVDC Boundary TopologicalNode-s are excluded), referenced by a cim:Terminal
5099              which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.
5100
5101          Note: An HVDC Boundary TopologicalNode has a cim:IdentifiedObject.description
5102          attribute with leading characters 'HVDC'.
5103
5104          Justification:
5105          In the Reporting Information Market Document, issued by PEVF or CGMA,
5106          the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
5107          of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the ControlArea
5108          instance.
5109
5110          Message:
5111          AC tie flows doesn't match the scheduled interchange values
5112          more than INTERCH_IMBALANCE_ERROR MW.
5113
5114          Usage: #IGMRuleSet #CGMRuleSet
5115
5116
5117    Rule: HVDCScheduleMatch1  Level: 7  Severity: WARNING
5118
5119          Details:
5120          The cim:SvPowerFlow.p value should match the value
5121          of the external schedule for the same cim:ControlArea
5122          EIC 'Y' code and with the same connectingLine_RegisteredResource EIC 'T'
5123          code within INTERCH_IMBALANCE_WARNING MW threshold. The following conditions apply:
5124          -   cim:SvPowerFlow related to boundary cim:EquivalentInjection-s  must be used but
5125              with negated value.
```

- cim:SvPowerFlow participates in the comparison if the cim:Terminal is a terminal of cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode (HVDC Boundary TopologicalNode), referenced by a cim:Terminal, which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.

Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description attribute with leading characters 'HVDC'.

Justification:
In the Reporting Information Market Document, issued by PEVF or CGMA, the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea instance. The EIC 'T' code is found in the TimeSeries in the connectingLine_RegisteredResource.mRID, in the IGM it is the value of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the Boundary point instance, the terminal is connected to.

Message:
HVDC flow doesn't match the scheduled interchange value more than INTERCH_IMBALANCE_WARNING MW.

Usage: #IGMRuleSet #CGMRuleSet

Rule: HVDCScheduleMatch2 Level: 7 Severity: ERROR

Details:
The cim:SvPowerFlow.p value shall match the value of the external schedule for the same cim:ControlArea EIC 'Y' code and with the same connectingLine_RegisteredResource EIC 'T' code within INTERCH_IMBALANCE_ERROR MW threshold. The following conditions apply:

- cim:SvPowerFlow related to boundary cim:EquivalentInjection-s must be used but with negated value.
- cim:SvPowerFlow participates in the comparison if the cim:Terminal is a terminal of cim:EquivalentInjection which is connected to a boundary cim:TopologicalNode (HVDC Boundary TopologicalNode), referenced by a cim:Terminal, which is also associated to a cim:TieFlow through cim:TieFlow.Terminal.

Note: An HVDC Boundary cim:TopologicalNode has a cim:IdentifiedObject.description attribute with leading characters 'HVDC'.

Justification:
In the Reporting Information Market Document, issued by PEVF or CGMA, the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea instance. The EIC 'T' code is found in the TimeSeries in the connectingLine_RegisteredResource.mRID, in the IGM it is the value of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the Boundary point instance, the terminal is connected to.

Message:
HVDC flow doesn't match the scheduled interchange value more than INTERCH_IMBALANCE_ERROR MW

Usage: #IGMRuleSet #CGMRuleSet

Rule: NetInterchangeMatch1 Level: 7 Severity: WARNING

Details:
For every cim:ControlArea of type interchange, the value of
cim:ControlArea.netInterchange should
not deviate more than INTERCH_IMBALANCE_WARNING MW from the sum of the
netted area AC and DC positions in the aggregated netted external schedules
(PEVF or CGMA) for the same scenarioTime and with the same EIC 'Y' code.
If no netted area AC or DC positions or netted external schedule can be found for
the control area this rule skipped.

Justification:
In the Reporting Information Market Document, issued by PEVF or CGMA, the
EIC 'Y' code is found in the domain.mRID, in the IGM it is the value of
attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the cim:ControlArea
instance.

Message:
cim:ControlArea netInterchange deviates more than INTERCH_IMBALANCE_WARNING MW from
netted area position.

Usage: #IGMRuleSet #CGMRuleSet

Rule: NetInterchangeMatch2 Level: 7 Severity: ERROR

Details:
For every cim:ControlArea of type interchange, the value of
cim:ControlArea.netInterchange should
not deviate more than INTERCH_IMBALANCE_ERROR MW from the sum of the netted
area AC and DC positions in the aggregated netted external schedules
(PEVF or CGMA) for the same scenarioTime and with the same EIC 'Y' code.
If no netted area AC or DC positions or netted external schedule can be found for
the control area this rule skipped.

Justification:
In the Reporting Information Market Document, issued by PEVF or CGMA,
the EIC 'Y' code is found in the domain.mRID, in the IGM it is the value
of attribute entsoe:IdentifiedObject.EnergyIdentCodeEic for the
cim:ControlArea instance.

Message:
cim:ControlArea netInterchange deviates more than INTERCH_IMBALANCE_ERROR MW from
netted area position.

Usage: #IGMRuleSet #CGMRuleSet

Rule: InconsistentTnBaseVoltage Level: 7 Severity: WARNING

Details:
All equipment with a direct association to cim:BaseVoltage connected to a
cim:TopologicalNode shall have a cim:BaseVoltage.nominalVoltage that deviates no more
than BOUNDARY_BV_MAX_DIFF from the cim:BaseVoltage.nominalVoltage of the cim:BaseVoltage
referenced by the association end cim:TopologicalNode.BaseVoltage.

Justification:
If the cim:BaseVoltage.nominalVoltage differs this may indicate a topology error.

```
      Message:
      cim:BaseVoltages.nominalVoltage at a cim:TopologicalNode differs
      more than BOUNDARY_BV_MAX_DIFF from the cim:BaseVoltage.nominalVoltage of the
connected equipment.

      Usage: #IGMRuleSet
```

10 LEVEL 8 VALIDATION: CONVERGENCE BEHAVIOUR AND CGM PLAUSIBILITY

10.1 CONVERGENCE BEHAVIOUR OF IGM

In this section the focus is on the convergence behaviour of the Individual Grid Model, before the actual merge is initiated.

The Individual Grid Models are expected to be based on a solved model in the local tool, which is expressed in the operating assumptions and topology derived from this solved case.

The only IGM specific rule is IGMConvergence first in section 10.3.

10.2 PLAUSIBILITY OF CGM

In this section the focus is on calculation results that impact credibility of the CGM solution, because the modelling assumptions for the IGMs with respect to the boundary flows do not reflect reality.

10.3 VALIDATION RULES

```
Rule: IGMConvergence  Level: 8  Severity: ERROR

      Details:
      This rule applies to IGMs only.
      It shall be possible to solve the power flow with the following power
      flow settings:
      - Full Newton Raphson power flow algorithm.
      - Switched shunt adjustment must be set to enabled for shunts used for
        voltage regulation.
      - Transformer tap adjustment is set to enabled.
      - Q limits shall be respected for EquivalentInjection,
        ExternalNetworkInjection, SynchronousMachines, SVCs and
        SynchronousCondensers (also for slack node/swing bus).
      - Distributed generation slack is set to enabled
         (proportional to GeneratingUnit.normalPF).
      - Maximum mismatch is set to 0.1 MW and 0.1 MVAr per node.
      - Controlled node voltage error convergence tolerance = 0.0001 pu
      (The largest difference between actual and scheduled voltage magnitude in
      per unit at each node where voltage is subject to control to a set point,
      and for which at least one of the devices participating in the control of
      bus voltage to its set point is not at a reactive power limit, must be less
```

```
5279        than the controlled bus voltage error convergence tolerance).
5280
5281        Justification:
5282
5283        Message:
5284        Power flow could not be calculated for IGM with required settings.
5285        Check diagnostic messages.
5286
5287        Usage: #IGMRuleSet
5288
5289  Rule: CGMConvergence  Level: 8  Severity: WARNING
5290
5291        Details:
5292        This rule applies to CGMs only.
5293        It shall be possible to solve the power flow with the following power
5294        flow settings:
5295        - Full Newton Raphson power flow algorithm.
5296        - Switched shunt adjustment must be set to enabled for shunts used for
5297          voltage regulation.
5298        - Transformer tap adjustment is set to enabled.
5299        - Q limits shall be respected for EquivalentInjection,
5300          ExternalNetworkInjection, SynchronousMachines, SVCs and
5301          SynchronousCondensers (also for slack node/swing bus).
5302        - Area interchange control is set to enabled.
5303        - Maximum mismatch is set to 0.1 MW and 0.1 MVAr per node.
5304        - Controlled node voltage error convergence tolerance = 0.0001 pu
5305        (The largest difference between actual and scheduled voltage magnitude in
5306        per unit at each node where voltage is subject to control to a set point,
5307        and for which at least one of the devices participating in the control of
5308        bus voltage to its set point is not at a reactive power limit, must be less
5309        than the controlled bus voltage error convergence tolerance).
5310
5311        Justification:
5312
5313        Message:
5314        Power flow could not be calculated for CGM with required settings.
5315        Check diagnostic messages.
5316
5317        Usage: #CGMRuleSet
5318
5319  Rule: TIConvergenceStatMissing  Level: 8  Severity: WARNING
5320
5321        Details:
5322        This rule applies to both IGMs and CGMs. cim:IdentifiedObject.description is added
5323  to State Variables profile as required attribute. The cim:IdentifiedObject.description
5324  of cim:TopologicalIsland shall have one the following string values: “converged” and
5325  “diverged” which represents the convergence status of the cim:TopologicalIsland.
5326
5327        Justification:
5328        It should be possible to conclude if a cim:TopologicalIslands has diverged or
5329        converged.
5330
5331        Message:
5332        Convergence status (cim:IdentifiedObject.description) is not provided for
5333  cim:TopologicalIsland.
5334
```

```
5335        Usage: #IGMRuleSet #CGMRuleSet
5336
5337  Rule: TIConvergenceStatDiverged  Level: 8  Severity: WARNING
5338
5339        Details:
5340        This rule applies to both IGMs and CGMs. Convergence status for
5341  cim:TopologicalIsland is diverged. The
5342        cim:IdentifiedObject.description of the cim:TopologicalIsland shall then
5343        contain the text "diverged".
5344
5345        Justification:
5346        It should be possible to conclude if a cim:TopologicalIslands has diverged or
5347        converged.
5348
5349        Message:
5350        Convergence status is diverged for cim:TopologicalIsland
5351
5352        Usage: #IGMRuleSet #CGMRuleSet
5353
5354  Rule: CGMConvergenceRelaxed  Level: 8  Severity: ERROR
5355
5356        Details:
5357        This rule applies to CGMs only.
5358        It shall be possible to solve the power flow with the following power
5359        flow settings:
5360        - Full Newton Raphson power flow algorithm.
5361        - Q limits shall be ignored (also for slack node/swing bus) meaning
5362          unlimited reactive resources.
5363        - Area interchange control is set to enabled.
5364        - Maximum mismatch is set to 0.5 MW and 0.5 MVAr per node.
5365        - Controlled node voltage error convergence mismatch = 0.0001 pu
5366        (The largest difference between actual and scheduled voltage magnitude in
5367        per unit at each node where voltage is subject to control to a setpoint,
5368        and for which at least one of the devices participating in the control of
5369        bus voltage to its setpoint is not at a reactive power limit, must be less
5370        than the controlled bus voltage error convergence mismatch).
5371
5372        Justification:
5373
5374        Message:
5375        Power flow could not be calculated for CGM with relaxed Q limits.
5376        Check diagnostic messages.
5377
5378        Usage: #CGMRuleSet
5379
5380  Rule: Congestion  Level: 8  Severity: WARNING
5381
5382        Details:
5383        This rule applies to both IGMs and CGMs.
5384        There should be no base case violations considering PATL limits.
5385        The rule is applied only for PATL limits in cases where there is a cim:SvPowerFlow
5386        at the terminal where the cim:OperationalLimitSet is.
5387
5388        Justification:
5389
5390        Message:
```

```
      Base case violation.

      Usage: #IGMRuleSet #CGMRuleSet

Rule: CGMTieFlowImbalance  Level: 8  Severity: WARNING

      Details:
This rule applies to CGMs only.
The sum of the solved tie flows for each cim:ControlArea of type
      interchange shall equal the cim:ControlArea.netInterchange plus/minus
      an INTERCH_IMBALANCE_EMF MW. i.e.
      o TFS less than or equal to cim:ControlArea.netInterchange +
            INTERCH_IMBALANCE_EMF MW
      o TFS greater than or equal to cim:ControlArea.netInterchange -
            INTERCH_IMBALANCE_EMF MW
      Where TFS (TieFlow sum) is computed as
      o TFS = sum(cim:SvPowerFlow.p) of cim:EquivalentInjection-s which cim:Terminal
connects to the same boundary point (cim:TopologicalNode) where there is a cim:Terminal
referenced by the association end cim:TieFlow.Terminal.

      Note: This rule is built on the fact that the CGM SV instance file and the updated
SSH instance files of IGMs are consistent hence contain updated values of cim:SvPowerFlow.
i.e. cim:EquivalentInjection has the same output as the flow of the interconnection in
the CGM SV instance file.

      Justification:

      Message:
      The sum of solved tie flows for a cim:ControlArea deviates from the cim:ControlArea
interchange tolerance INTERCH_IMBALANCE_EMF MW.

      Usage: #CGMRuleSet
```

11 ANNEX A: SUPPORTING DOCUMENTS, FOR INFORMATION ONLY

11.1 INTRODUCTION

This section contains references to documents that support the rules.

11.2 QOCDC REFERENCE DATA DOCUMENT

The QoCDC Reference Data document provides all reference data e.g. enumerations and shared resources needed when validating the rules defined in this QoCDC document.

11.3 RULE DESCRIPTIONS

In section 12 a format for documenting rules is described. The rules are documented in XML files based on this format and one XML document per level exists. The XML documents are machine

processable enabling translation to other formats to avoiding copy and pasting from the QoCDC word document. The xml documents are provided for information only.

The XML documents can be found in the archive “QoDCRules 3 edition.zip” that is available for download from ENTSO-E file repository together with this QoCDC document.

12 ANNEX B: DESCRIPTION OF RULES, FOR INFORMATION ONLY

This section is for information only and suggests possible implementation solutions.

The rules in XML format are created to support implementers to they can use rule descriptions, severity, level, message etc. in their development if they want. The reporting format is just an example and has not been coordinated with existing tools reporting rule errors or warnings.

Creation of a complier-based solution, as suggested below, is by no means required by this document. It is just a hint that this is possible based on existing solutions, e.g. Eclipse Modelling Framework (EMF).

The validation rules are described by XML templates where several XML elements describe the information. The template describes not only the rule but also additional information useful in error or warning messages. The XML format is not so easy to read, hence the rules listed in the following sections are listed in a format that is easier to read. The simplified format contains the following information

- Rule name that also identifies the rule.
- Rule level, 1 to 8.
- Rule severity, ERROR or WARNING.
- Template used, RuleFile, RuleObject or RuleModel.
- Details that describe the rule.
- Justification for the rule.
- Message text.
- SourceFile.

The severity ERROR should block publishing an IGM or CGM in level 1 to 6. This document does not limit use of additional severities that an implementation may want to use, e.g. ALERT, INFO, COMMENT etc.

For each rule the XML template is filled in with information describing the specific rule. The template also contains information about a detected error or warning which means that the template contains two types of information:

- Description of the rule itself that is created at design time included in this document
- Description of actual errors or warnings created at validation time.

The XML template is described by an XML Schema (XSD) which means that the rule descriptions in this document as well as reported error or warning can be validated by the XSD.

The conditions that cause errors or warnings are described by English text in the rules. This means that this text needs to be translated into machine readable and executable code to perform the validation. UML contain a language for this, the Object Constraint Language (OCL), that is machine readable. The OCL code can be executed

- By translation into some executable language as Java, C#, C++, C, Python etc.
- By translation to a XML based language that can be validated by an XSD, note that the XML templates in this document do not have this capability.
- Directly by an OCL engine

The translation referred in the two first bullets can be either done manually or by a compiler. As existing rules are expected to change, and new rules will be created, manual translation shall not be used.

Three types of rule templates are defined, Figure 15**Error! Reference source not found.**.

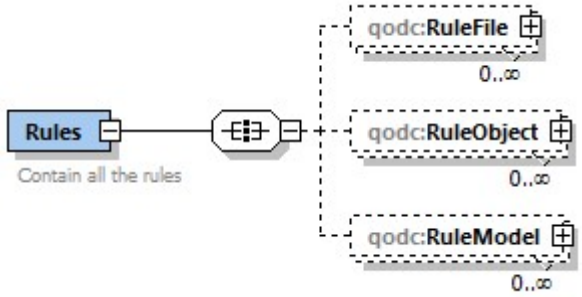
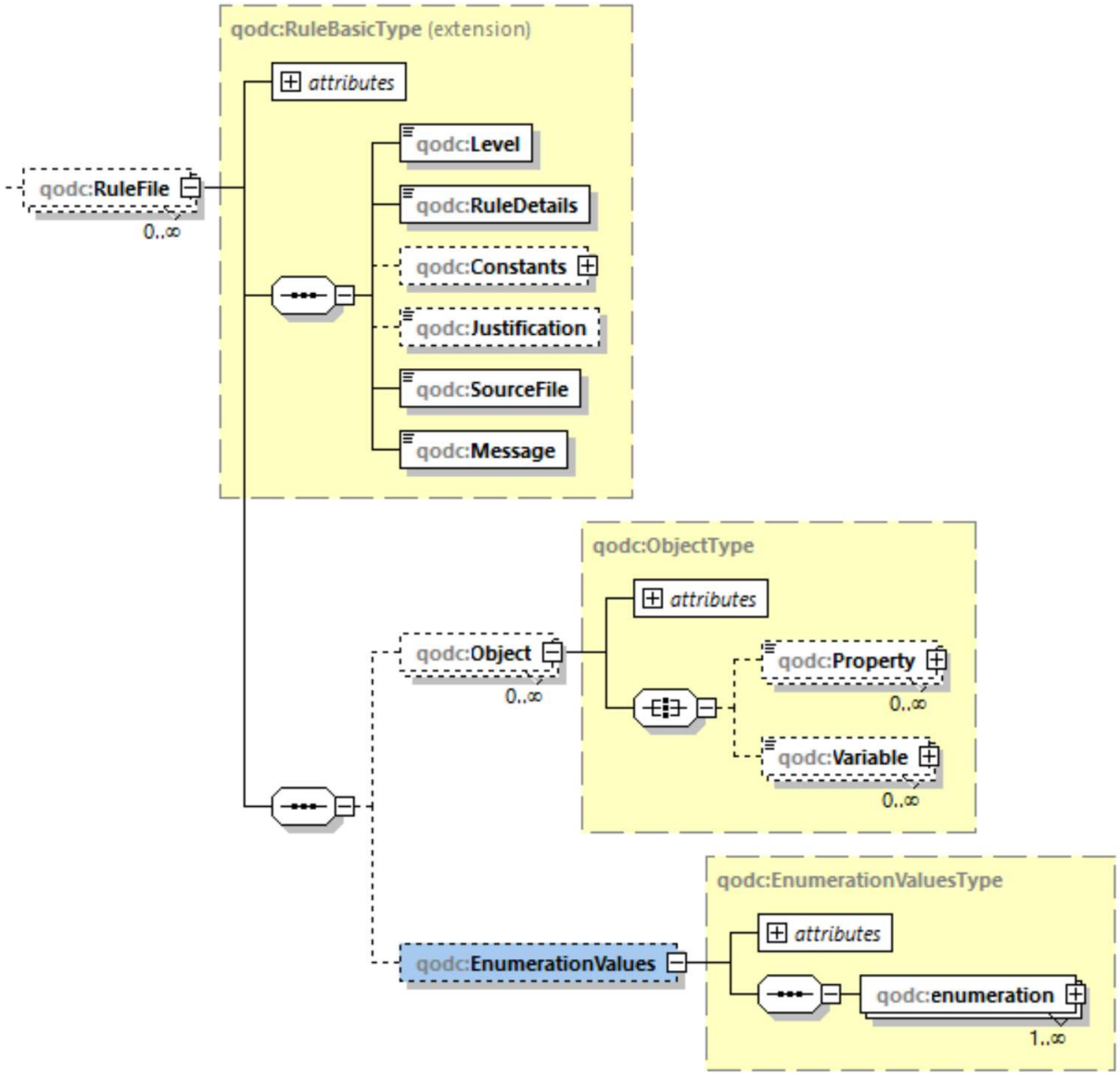


Figure 15 Rule template types

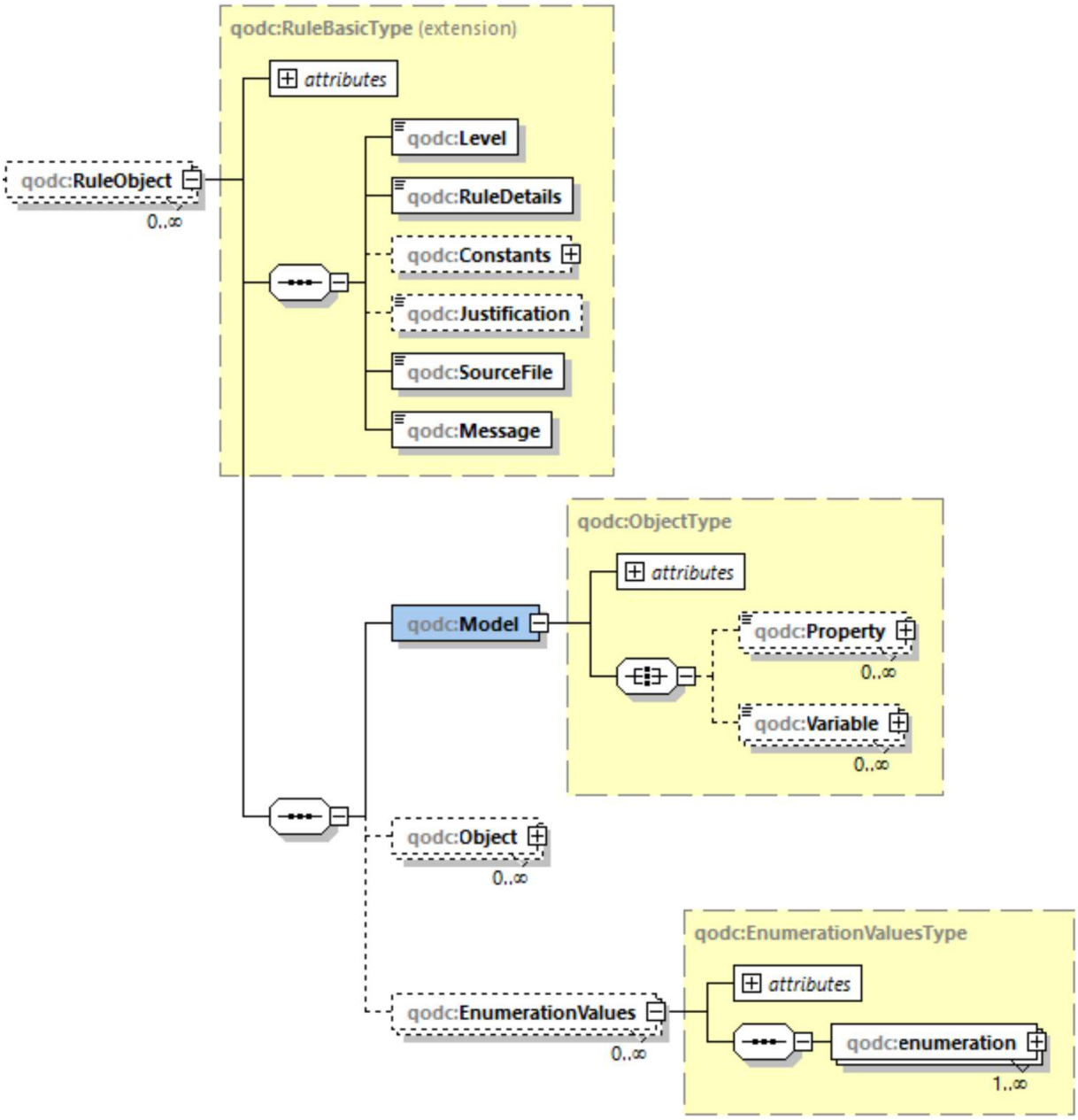
Rule templates describing CIMXML file related errors are described in Figure 16**Error! Reference source not found.**.



5487

5488 **Figure 16 Rule template for file related errors**

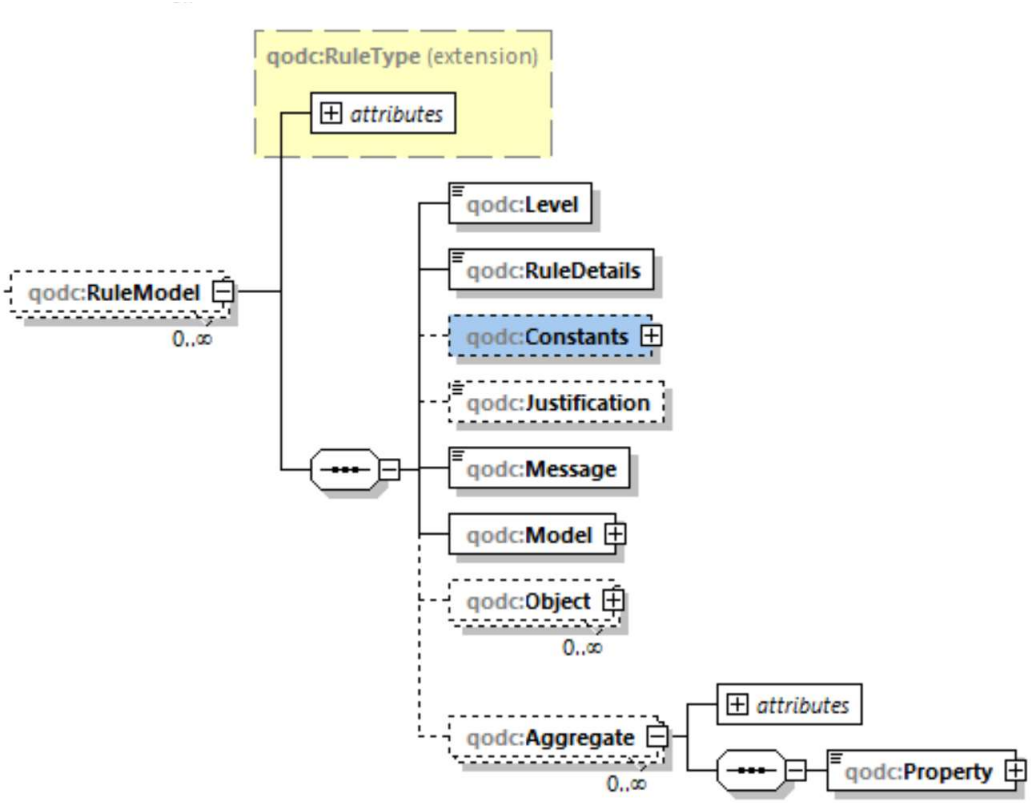
5489 Rule templates describing object related errors are described in Figure 17**Error! Reference source**
5490 **not found.**.



5491

5492 **Figure 17 Rule template for object related errors**

5493 Rule templates describing errors related to the whole model are described in Figure 18**Error!**
5494 **Reference source not found.**.



5495

5496 **Figure 18 Rule template for model related errors**

5497 The following tables specify the XML elements and attributes.

5498 **Table 4 Attributes of qodc:RuleFile, qodc:RuleObject and qodc:RuleModel**

Attribute name	Description
qodc:ruleID	String that holds the name of the rule, the name shall be unique.
qodc:severity	Enumerated values that specify the behaviour of the validator: “ERROR” means that the data will be rejected “WARNING” means that the data will be used in further processing, but impacts the quality of the calculation results.

5499 **Table 5 Additional elements of qodc:RuleFile and qodc:RuleObject**

Element name	Description
qodc:Level	Integer value indicating the validation level as described in section 0.
qodc:RuleDetails	English text that describes the condition causing a report of an error or warning. As discussed in the introductory part of this section there is if possible, a corresponding OCL rule describing the condition.
qodc:Constants	An optional named constant. Rules may have constant values, e.g. limits, that are used in several rules. Multiple appearances of the same value allow for mistakes in case the value is changed. Hence the named constant defines the

	allowed value and any change will then result in validation errors which makes it easy to find and correct the values that need to be changed.
qodc:Justification	String that specifies what the rule is based on (optional).
qodc:SourceFile	String that specifies the XML file Name of the XML file being validated.
qodc:Message	String that specifies the message that must be displayed.
qodc:Object	Specification of an CIM object causing a report.
qodc:Property	Specification of a property with value belonging to the CIM object causing a report.
qodc:EnumerationValues	An enumeration list of allowed values. The element as an optional qodc:description attribute that can be used to further describe the meaning of the qodc:EnumerationValues.

5500 **Table 6 Attributes and elements of qodc:Object**

Attribute name	Description
qodc:cimref	The CGMES class of the object causing a report.
qodc:mRID	Identification of the object causing a report.
qodc:Variable	A variable that holds a value that is computed in the validation rules. The purpose of variables is to allow inclusion of computed values in the error or warning report.

5501 **Table 7 Attributes of qodc:Property**

Attribute name	Description
qodc:cimref	The CGMES attribute or role name of the property.

5502 **Table 8 Attributes of EnumerationValues**

Attribute name	Description
qodc:enumeration	A enumeration member.
qodc:value	The enumeration value.
qodc:description	An optional description of the qodc:value.

5503 **Table 9 Elements of qodc:RuleModel**

5504 For elements common with RuleFile and RuleObject refer to **Error! Reference source not found.**
5505 to **Error! Reference source not found.**.

Element name	Description
qodc:Model	The Model class in the IEC 61970-552.
qodc:Aggregate	Implies that an aggregate calculation shall be made for a collection of objects. The calculation may be a sum, mean value, max value etc.

5506 **Table 10 Attributes and elements of qodc:Model**

Element name	Description
qodc:cimref	The IEC 61970-552 Model class.
qodc:mRID	Identification of the Model object causing a report.
qodc:Property	Specification of a property with value belonging to the IEC 61970-552 Model class. For details refer to **Error! Reference source not found.**.
qodc:Variable	A variable that holds a value that is computed in the validation rules. The purpose of variables is to allow inclusion of computed values in the error or warning report.

Table 11 Attributes and elements of qodc:Aggregate

Attribute name	Description
qodc:cimref	The CGMES class for which the aggregate is calculated.
qodc:type	The type of aggregate calculation, e.g. sum. The XSD include the currently supported aggregate calculations.
qodc:Property	Specification of a property with the aggregate value included in the calculation. For details refer to **Error! Reference source not found.**.

Table 12 Attributes of qodc:Variable

Attribute name	Description
qodc:nameOfVariable	A variable has a name that describes the meaning of the variable and indicates how the value is computed, hence the variable name may be long.

Below follow the examples of XML rule templates.

```
<qodc:Rules                          xmlns:qodc="http://entsoe.eu/CGMES2_4_15/QoCDC/3/2"
xmlns:xsi="w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="entsoe.eu/CGMES2_4_15/QoCDC/3/x file:QoDCRules.xsd">
  <qodc:RuleObject qodc:ruleID="GenerationContainment" qodc:severity="ERROR">
    <qodc:Level>3</qodc:Level>
    <qodc:RuleDetails>
    For every instance of HydroPumps and GeneratingUnit (and subclasses
    thereof), the cim:Equipment.EquipmentContainer referred to,
    must be of type Substation. Missing containment is not allowed.
    </qodc:RuleDetails>
    <qodc:Justification>
    See Figure 15 (Core notes) of IEC TS 61970-600-2
    </qodc:Justification>
    <qodc:SourceFile>
      <!-- Name of the XML file -->
    </qodc:SourceFile>
    <qodc:Message>
    HydroPumps and GeneratingUnit must be contained in a Substation
    </qodc:Message>
    <qodc:Model qodc:cimref="" qodc:mRID="">
      <!--    md:FullModel    or    dm:DifferenceModel    class    name    given    in
qodc:Model/@qodc:cimref-->
```

```
5533        </qodc:Model>
5534        <qodc:Object qodc:cimref="" qodc:mRID="">
5535          <!-- Class name given in qodc:Object/@qodc:cimref -->
5536          <qodc:Property qodc:cimref="cim:IdentifiedObject.name">
5537            <!-- Name of object -->
5538          </qodc:Property>
5539          <qodc:Property qodc:cimref="cim:Equipment.EquipmentContainer">
5540            <!-- Erroneous container class reference given in
5541                 qodc:Property/@qodc:cimref -->
5542          </qodc:Property>
5543        </qodc:Object>
5544      </qodc:RuleObject>
5545
5546
5547
```